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SUMMARY STATEMENT UPON THE PROPOSED REVISIONS OF THE CONSTITUTION AND BY-LAWS. *H. S. Rogers* 599

REPORT OF THE COMMITTEE ON ACADEMIC TENURE, PROFESSIONAL SERVICE AND RESPONSIBILITY 601

GROUND SCHOOL AND ENGINEERING SCHOOL: SOME NOTES ON TRAINING. *George D. Stout* 612

PATENT POLICIES FOR SPONSORED RESEARCH. *R. A. Morgen* 618

I THINK—. *B. F. Bailey* 621

SELECTIVE SERVICE. *M. H. Trytten* 626

CONDENSATION OF A REPORT ON COURSE XV, M.I.T. *R. W. King* 634

TECHNICAL EDUCATION FOR ENGINEERS IN ENGLAND. *W. Abbott* 653

THE BUILDERS OF THE BRIDGE. *John Charles Riedel* 657

SECTIONS AND BRANCHES 671

COLLEGE NOTES 672

SELECTION AND GUIDANCE. *K. W. Vaughn* 676

INDEX 685

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Summary Statement Upon the Proposed Revisions of the Constitution and By-Laws

By H. S. ROGERS
Chairman, Committee on Revision of Constitution and By-Laws

This is the last editorial in the series which has presented the purpose and the actions of the Committee on Revision of Constitution and By-Laws under the directive "to review the Constitution and By-Laws of the Society for the purpose of adapting the organization of the Society to the needs of the present time and submit such recommendations as the Committee sees fit to the Council."

The first of the series was presented in the September Journal and there has been one in each succeeding publication. Through them the Committee has endeavored to make clear to the members of the Society the objectives of the revisions, and to present these revisions in final form. Before this is in print members of the Society will receive a complete categorical statement of the separate actions which must be taken to effect the changes in the Constitution recommended by the Committee and the Council. This final text has had the approval, without dissenting vote, of the Committee and the Council. We shall probably find that it is not a perfect document but subject to some variations in interpretation, and some omissions. It represents, however, the honest and sincere efforts of the Committee to discharge the task assigned to it by the Council and also contains the constructive suggestions of scores of members of the Society.

Three tentative drafts were prepared prior to the final text. They were circulated to members of the Council and to the Committee who are distributed through all sections of the country and who number, with allowances for overlapping, fifty-seven people. Many of these in turn discussed the draft copies with fellow members of the Society. None of the preliminary drafts circulated was intended as a finished document. On the other hand each represented what the Committee was able to do in the time available to it in one of the scheduled meetings. All drafts, however, received the careful scrutiny of those to whom they were sent and the Committee received scores of letters suggesting revisions and amendments. All of these letters were carefully considered and many of the suggestions were incorporated into the final text.

The Committee feels therefore that this document represents, within the limits circumscribing all such documents, the best it could produce. The present organization of the Society for the individual members has been changed but little. The classification of members, the dues, the outline of structure, and the responsibility of the officers remain the same. The mem-

bership of the Council has been changed to give wider and more direct representation to the Divisions and Sections of the Society, and the responsibility for the publications has been placed in the hands of the Executive Board where in tradition it has always reposed.

The institutional membership, on the other hand, has been organized collaterally with the individual membership in its relationship to the Executive Board. It has no control however in any way over the General Council and the regional activities and instructional divisions. It has been placed in this position for the purpose of getting unified action and direct expression upon the problems that confront engineering school administrators. The proposed structure will encompass all of the organized activities of the engineering schools within one organization which will have corresponding strength and prestige.

It is now our conviction that the revisions are ready for action by the Society at the St. Louis Convention. If the articles appearing in the JOURNAL have been carefully studied the Society should be fully informed upon the purpose and the nature of the revisions and should be ready to act upon the proposals. The proposals will, therefore, be presented to the tender graces of the membership with the hope that it will find in them an instrument for "adapting the organization of the Society to the needs of the present time" and that it will recognize the opportunity to take care of any adjustments in future revisions should they seem necessary.

Report of the Committee on Academic Tenure, Professional Service and Responsibility

This committee was appointed by, or at the suggestion of, the Executive Committee of the Society's Division of Administrative Officers of Engineering Colleges, and was instructed to prepare a "report . . . which could guide the engineering colleges with reference to tenure, consulting service and professional responsibility."

The instructions are altogether timely. The colleges and schools of engineering were seriously disturbed by the war and by the emergency period which preceded the war. Their staffs were disrupted, their students dispersed and their standards were sometimes lowered. Hence, it seems desirable to reexamine and restate the reciprocal responsibilities of engineering institutions and their staffs, and to codify those personnel criteria and policies most likely to strengthen engineering education in the post war era.

In order to do so, it is necessary to take into account the relations which have been established between the institutions, the profession and the engineering industries. For instance:

1. The national professional engineering societies have established student branches in most of the engineering schools. These branches provide opportunities for the students to speak before professional bodies, to organize and manage group activities, and to develop an appreciation of professional traditions, ideals and standards.

2. The Engineers' Council for Professional Development has established standards and procedures for the accrediting of engineering curricula, for selection and guidance of students, and for professional training and recognition.

3. Industrial and engineering corporations send representatives to the schools to lecture on their specialties, and to interview upper classmen for the recruitment of their technical staffs. These representatives might well keep a close check upon the work of the schools and of the graduates of the schools whom they employ.

4. Many schools conduct engineering research in cooperation with industries and the government, and with technical societies and associations, and members of engineering faculties render consulting services to engineering industries and to the profession during vacation periods, leaves of absence, or, on a part time basis, during the regular sessions.

5. Faculty members occasionally leave engineering schools permanently for employment in the industries or with firms of engineers, and engineers occasionally leave industry or practice to join engineering faculties.

This is a wholesome interchange although it may result in direct competition between industry and engineering schools for the services of faculty members. College positions have certain at-

tractions other than salary—indeed, they need to have—but too great a discrepancy between college and industrial salaries will attract the more competent men into the industries and leave the less competent in the colleges, with resulting damage to engineering education and, ultimately, to the industrial economy and the well-being of the community.

The Status of the Engineering Faculty Member in his Institution

College teachers of engineering and of the related sciences and humanities are first of all members of the academic profession and share equally with their colleagues in other fields its privileges and obligations. Many personnel usages of higher institutions are equally appropriate for teachers of engineering and for others; some of these usages may warrant modification to cover distinctive conditions, such as outlined below. When such modifications are proposed, it seems expedient to hold to widely accepted procedures and codes wherever possible, and to propose alternatives and reservations which can be applied without disrupting institutional practices. Less than one-third of the institutions which have accredited engineering curricula are primarily technological in character; in most of the others the teaching personnel is preponderantly academic rather than technical or professional in background and attitude.

Of the conditions distinctive to teachers of engineering and the technical sciences, the following are believed to be the most significant:

1. Engineering and industrial experience and other forms of advanced training than the earned doctorate are generally considered to be equally appropriate as preparation for the teaching of engineering, and in some branches more appropriate. Proper equivalences should be recognized in qualifying standards for appointments and promotions.

2. Many engineering teachers have received less extended and profound training in the sciences underlying their work than their academic colleagues of equal rank and responsibility. There is therefore somewhat greater risk that radical advances in knowledge and practice may make their training progressively inadequate in their mature years.

3. The teacher of engineering benefits in rank and salary, as compared with most academic colleagues of equal age, training and attainment, by reason of industrial or professional competition for his services. He usually has a smaller economic investment in his training, and has less need of economic protection through tenure by reason of opportunities to transfer into professional or industrial practice.

4. The closely prescribed and articulated character of engineering curricula makes it important to assure adequate safeguards against ineffectual teaching and failure to maintain technical competence in step with advancing knowledge and practice. Most of the courses in a curriculum have essential tool values and the engineering student is seldom afforded a choice of teachers. He is therefore less able to protect himself against an ineffective teacher than the academic student in a highly elective curriculum.

The logic of the situation thus summarized seems to warrant greater flexibility in matters of appointment, promotion, salary, tenure and departmental headships than commonly prevails in academic circles. The matter of acad-

emic freedom presents few problems in engineering education; the usual safeguards are appropriate, such as those adopted and published by the Association of American Colleges.*

This outline of personnel usages for engineering faculties and institutions is presented in skeleton form with a view to future elaboration:

Appointments, Promotions and Headships

1. Qualifying standards for each academic rank should be formulated; they should be distinctive to engineering; they should be as objective as possible in their specifications; they should recognize a reasonable equivalence between attainments through experience and through higher graduate training, but should in all cases require fundamental knowledge considerably beyond that associated with the bachelor's degree; and they should not base advancement, rank or responsibility upon length of service, except incidentally.

2. Gradations of rank and responsibility should recognize both different levels of intellectual attainment and authority and different levels of responsibility for planning and supervision.

3. In all appointments and promotions, due measure of recognition should be given to effective teaching, and to research, contributions to professional knowledge or practice, contributions to organized professional activity and contributions to campus life and relations.

4. Senior rank should be reserved for men of genuine professional or scholarly authority, and with rare exceptions, such authority should be well established in off-campus circles.

5. Headships of departments or other administrative units should be subject to change without necessarily affecting academic rank and tenure; in many cases headships should be relinquished by rule at an earlier age than that set for final retirement.

Tenure

1. There should be a junior status, carrying year-to-year or short term appointments.

2. There should be an introductory term of definite length in all new appointments, and in promotions to the professional ranks.

3. Indefinite tenure should be attained at a level of age, experience and responsibility such as to afford assurance of:

(*a*) the completion of all formal preparations for a teaching career,
(*b*) the attainment of authority in some scholarly or professional area,
(*c*) effectiveness as a teacher,
(*d*) reasonable stability of career aims as a teacher,
(*e*) capacity and will to maintan teaching effectiveness and continued growth.

4. Tenure should be conditional, with proper safeguards against arbitrary discrimination, upon:

(*a*) the continued inclusion of the individual's field of specialization in the program of instruction,
(*b*) adequate enrollment in the individual's field of work, with due allowance for transient fluctuations,
(*c*) regular and punctual performance of work,

* *Association of American Colleges Bulletin*, Vol. 27, No. 1, March, 1941, pp. 124–125 and 127–128.

(*d*) observance of academic and professional ethics,

(*e*) maintenance of adequate training, knowledge, experience and contacts to keep abreast of developments in the individual's area of responsibility.

5. Termination of appointments should be upon adequate notice, for sufficient cause and with all reasonable effort to assure to the individual alternative opportunity for employment of suitable grade.

6. Policies on appointment, promotions and tenure should be published to the faculty.

Salary Schedules

1. Salaries should be adequate to attract and retain teachers of sufficient competence to accomplish the aims of the institution and of the engineering profession.

2. Salary scales for the various academic ranks should be established and generally known; individual salaries, however, should be confidential.

3. Increases at stated intervals and amounts should obtain only in junior ranks; in the more advanced ranks each individual should be at a level corresponding to his responsibilities.

4. The salary of a staff member should be adequate to compensate him for his full-time duties, without the payment of supplementary compensation for special assignments. Some institutions, however, occasionally engage their regular staff members during the academic year for work beyond the normal full-time load and provide additional compensation accordingly. Such supplementary compensation is usually necessary when the extra assignments require the staff member to give up desirable sponsored research, outside consulting or other work.

In general it seems clear, however, that the institution and its staff are better served when overtime work and compensation are avoided by payment of an adequate regular salary and the freeing of the staff member from usual duties to undertake special assignments. Any overtime plan which diminishes a staff member's opportunity and incentive to undertake professionally important and valuable technical work, with the attendant opportunity to widen his experience and thus strengthen his teaching, should be avoided.

If equity demands that supplementary compensation should be paid for extra work within an institution, the amount of such additional compensation should not be so high that it tends to reduce the importance of the staff member's regular work and salary, and to place a value of contract research or nonacademic assignment that is high in relation to the value placed on the usual academic duties.

Care must likewise be exercised to avoid compensation inequities within an institution which result when some staff members, whose field of work may attract outside research, receive large supplementary salary payments while other staff members, in fields of less immediate application, but possessing equal or greater scholarship and professional standing, receive from the institution only their regular salaries. No plan of supplementary compensation should put teaching in an inferior position or tend to divert staff members from their obligations to their students.

Retirement

1. Retirement should be optional before a specified age, but obligatory at that age. Post-retirement appointments, if made at all, should be on a

year-to-year basis and should not retard the advancement of younger men.

2. A definite retirement income, based on the individual's service record, should be assured, preferably on a contributory basis.

3. If an individual's retirement is arranged before the specified age in the interest of the institution, an equitable adjustment should be made in the retirement income.

Professional Practice

There has been some difference of opinion concerning professional practice by members of engineering faculties. There are those, among the faculties of colleges of literature, science and the arts, among practicing engineers and even among engineering teachers, who held that members of the engineering faculties should not engage in private professional practice, at least not during the semesters or other periods when they are actually teaching.

However, there seem to be excellent reasons why teachers of engineering should be permitted to practice independently. Such practice, for example:

(*a*) renders professional service;

(*b*) vitalizes teaching through the "cross-fertilization of theory and experience";

(*c*) indirectly provides helpful contacts for students in the profession and in the industries;

(*d*) augments the professional stature of the faculty member, as the limited laboratory facilities of colleges and schools do not permit the full development of engineering projects. No schools, for instance, have full sized equipment for the manufacture and treatment of metals. These are available only in the industries. Accordingly, only work in conjunction with mills engaged in the production of metal products provides the engineering teacher with a full-scale laboratory;

(*e*) satisfies the familiar requirement, in many cases, that the university teacher must undertake at least some research projects for the extension of the borders of knowledge.

As a matter of fact, very many engineering teachers do engage in private practice, engineering teachers always have practiced, and abundant precedent for practice can be found in other professions. Many of the faculty in American dental and medical schools engage in practice on their own, although medical and dental schools operate clinics for the public service.

The private practice of engineering faculties should be subject to reasonable restrictions as follows:

1. No member of the engineering faculty should undertake professional practice unless this practice advances his scientific and technological knowledge, with consequent benefit to his teaching skill and total competence. The faculty member hardly meets this requirement if he accepts trifling commissions which do not in the slightest challenge his powers and resourcefulness.

2. No faculty member should engage in practice which interferes with his teaching duties, which have priority at all times. Teaching duties are considered to include not only actual meeting and working with classes, but also conscientious preparation of class material, reading of reports and papers, development and revision of courses and guidance of and conferences with individual students.

3. No faculty member should practice in direct competition with established consulting engineers. The teacher should not, as such, advertise that he is available for consulting service. However, when he possesses expert and special knowledge, and his services are sought because of that fact, he has the distinct obligation to place himself at the disposal of the industries and the community, provided, of course, that his doing so will not interfere with his primary school or college duty.

The Responsibility of the Engineering Faculty Member to his Institution and its Students

The engineering teaching staff has the exacting dual responsibility of providing both a specialized education keyed to the rigorous standards of professional practice, and a generalized education affording the student a broad outlook which is essential to effective citizenship and to interests beyond the practical and vocational. The individual staff member must extend his own special competence in a manner to contribute to this twofold responsibility. He must recognize that he owes to his institution and its students the following three independent types of service:

1. Teaching of the Highest Order

He must master the technique by which knowledge is conveyed to young minds. To accomplish this he requires not only some competence and experience in his specialized field, but the skill to awaken interest and the patience to understand the individual. He requires the capacity to look beyond the subject which he teaches and to guide the student to see its implications and relationships. He must exert effort in the art of teaching and must appreciate that effective teaching is not confined to formal class and laboratory exercises but includes all those relations with the individual and the group, both curricular and extra-curricular, which stimulate intellectual activity.

The experienced teacher understands his obligation to all his students but always keeps in mind that his inspiration of one student to notable achievement may be a more important accomplishment than leading a score merely to pass. Neither popularity among undergraduate students nor the ability to tutor them successfully through examinations is necessarily evidence of good teaching. Favorable judgment of advanced students or alumni is more likely to constitute such evidence. Still other criteria of good teaching are development of younger members of the faculty and stimulation of the imagination of students, to create in them the urge constantly to set for themselves higher or more difficult goals.

To supplement these hallmarks of good teachers in all fields, the engineering teacher has certain specialized opportunities and obligations. He must use effectively the three processes of engineering education: lecture-recitation, laboratory and design.* Through these processes he must give the student understanding of scientific method, mastery of fundamentals and facility in their application. He must be resourceful in devising and using problems to develop the student's capacity to think both quantitatively and accurately. He must be prepared, moreover, to impart to his students some competence in the art of engineering: the synthesis of technological knowl-

* "Report of Committee on Engineering Education After the War," Journal of Engineering Education, Vol. 34, May, 1944, pp. 589–614.

edge, a sense of costs and engineering judgment.

2. Advancement of Knowledge

The staff member who is still intensively learning, whether it be new, fundamental relationships, or sounder and more economical ways of applying knowledge, can best guide those who seek to enter upon a professional career. This continuing obligation to learn is therefore essential to engineering teaching of the highest order; it is also essential as an activity distinct from teaching. The faculty member must have a relish for discovery, and must accept intellectual inquiry and advancement of knowledge as obligations of his profession.

In an engineering institution these obligations usually are carried out by the faculty member's professional practice and consultation or by original research. Research is important not only because it advances knowledge but also because it is a method of teaching when carried on in collaboration with students. At advanced levels of teaching, example is more effective than precept; the teacher inspires by accomplishment rather than by words.

3. Responsibility to Institution

To be an effective teacher and to advance knowledge are the obvious responsibilities of the faculty member, but he may need to share in other responsibilities essential to the functioning of his institution. Efficient and imaginative planning and administration of the over-all educational program are necessary. Service to industry, to the community and to government is a recognized institutional obligation. These four—teaching, advancement of knowledge, administration and public service—comprise the principal opportunities and responsibilities of the staff member.

Effective collaboration with colleagues is an additional obligation. Within any departmental group, the ideal is to have a team which includes creativeness, teaching ability, professional competence and leadership in proper balance. The individual as well as the group must work for this balance, and must be loyal in cooperating with other departments and units to promote the unity and welfare of the institution as a whole.

There is the further problem of balancing private practice with institutional responsibility, which has already been considered. The institutional duties of the faculty member have priority, and before undertaking outside obligations, he should consult his Administrative officer regarding the relation of the outside activities to his academic work, so that both may be properly balanced and coordinated with the activities of his colleagues.

To render effectively the types of service which have been discussed, the engineering teacher, in summary, must assume his proper share of the following responsibilities of the faculty as a whole:

Teaching

(*a*) Preparation of materials, synthesis of existing knowledge and development of educational methods suited to the student's stage of advancement.

(*b*) Study for the purpose of keeping abreast of the profession and for inproving teaching skill.

(*c*) Writing of texts to expound the results of scientific or engineering research, or to revise teaching technique.

(*d*) Participation in the work of educational organizations, especially those dedicated to the perfecting of teaching.

(*e*) Consultation with colleagues for the purpose of advising them concerning their problems; especially, counseling younger staff members.

(*f*) In general, development of a complete teaching competence which stimulates in the student intellectual initiative, professional ability, the faculty of sound judgment and criticism, and a sense of responsibility for the humane use of learning.

Creative Scholarship

(*a*) Scientific or engineering research or other intellectual inquiry to advance knowledge or improve an art.

(*b*) The publication of work results in scholarly monographs, research papers or books, or the filing of applications for patents of inventions.

(*c*) Consultation or professional practice when this contributes to personal growth, to vitalizing teaching and to the public welfare.

(*d*) Activities in professional societies for the advancement of scholarship or of engineering.

Service to the Institution

(*a*) Administrative and committee work and professional service for the solution of internal institutional problems.

(*b*) Services to sister educational institutions and to other institutions maintained for the public benefit.

(*c*) Academic and personal counseling to assist the student to make the most of his opportunities.

(*d*) Guidance and direction of students in worth while extra-curricular activities.

(*e*) Representation of the institution before the public and otherwise as may be necessary or advantageous.

Responsibility of the Engineering Educator to the Profession

Engineering educators have always recognized their responsibility to the profession. They made this recognition explicit in June, 1944, when the Society for the Promotion of Engineering Education approved without hesitation the report of the Society's Committee on Engineering Education After the War. By this action the Society officially accepted the Committee's statement that "Engineering education . . . is responsible to the engineering profession for the maintenance of proper educational standards and for the inculcation of ethical attitudes and conduct among its graduates." *

Fully to explore this responsibility is out of the question for the present, but it may be timely to suggest certain duties which seem to derive from this responsibility:

1. The engineering educator should be professional himself, or aspire to be if he is a novice, which means that he should be concerned with those sectors of engineering "which are performed on a high intellectual level, with an intricate technique and with a high de-

* Journal of Engineering Education, Vol. 34, May, 1944, p 590.

gree of responsibility both to client and to society." *

2. The engineering educator must be loyal to his profession. He should belong to and cooperate with one or more of the great engineering societies to which American engineers have entrusted their profession's well-being.

3. He should exert himself to maintain a high level of efficiency in the schools and colleges. This responsibility has been discussed in a preceding section of this report. In the tangible phase of the task, which pertains to the sciences and their application, the engineering teacher knows his work and does it well enough. More perplexing is the elusive business of preparing the student for citizenship and for his complete destiny—the humanistic-social stem. Not until recent years have engineering educators realized that their responsibility for this phase of education is as grave as for the other.

4. The educator must protect his profession by weeding out unqualified students. He cannot know which students will finally become truly professional and which will enter upon the larger sphere of auxiliary engineering occupations, but it is his duty to the profession to eliminate at least those students who clearly are not fitted even for the marginal engineering employments.

5. The engineering educator has the additional and important duty of inspiring his students to strive for progress and achievement, and to continue to study throughout their careers. He must cultivate in them an appreciation of professional ideals and purposes, particularly the important obligation of ministering to the people and to the community.

6. The educator, finally, is responsible to his profession for developing the character of his students.

This is possibly the paramount and most challenging of the engineering educator's many obligations. Character is the most essential qualification of the engineer. This was the opinion of 94.5 per cent of 7,000 engineers who cooperated in the preparation of the Mann report. And engineers of the present generation agree, although most of them doubtless have in mind the particular element in character known as integrity. "By common consent, the quality most universal and indispensable among engineers is integrity; this is essentially something moral or idealistic." *

Engineering teachers are deeply concerned about their responsibility for the integrity of students, and have discussed the problem eloquently and at great length in their meetings and conferences, but all of them doubtless are convinced that their efforts to instill moral understanding and appreciation have fallen far short of their aspirations.

Some of them are of the opinion that results can be accomplished in this area of education only by example, and that anything like precept will be futile.

More of them would be willing to attempt actual teaching if they knew what to teach, other than the brief codes of the engineering societies.

The Society's Committee on Engineering Education After the War declares that the student "should also, as a guide to critical, ethical and moral

* "Report of the Investigation of Engineering Education," Society for the Promotion of Engineering Education, Vol. II, Pittsburgh, 1934, pp. 1085–6.

* "The Second Mile, a Re-survey," Engineers' Council for Professional Development, New York, 1944, p. 13.

values, have some acquaintance with the great enduring humanistic ideals which men have evolved." * But exactly which are the "great enduring, humanistic ideas?" They must be identified before they can be taught. How is the educator to identify them?

Little help can be expected from science. The physical sciences have been exceedingly fruitful in engineering technology; so far they have been equally sterile in the technology of human conduct.

The Committee on Engineering Education After the War insists that "The natural detachment so desirable in science will not suffice . . . where concepts of value and motivation of social conduct are involved." † On the other hand, emotion and conjecture will be no more effective in establishing standards for conduct than in any other field of learning or instruction. Any standard of moral responsibility must have a completely rational basis.

Criteria of morality do not exist, as a matter of fact. There is a traditional conscience of American citizens. It is a matter of universal experience that men have within them an imperative, whereby many times a day, they distinguish between what they hold to be right and what they hold to be wrong.

At the present time, no solution of the problem of ethical subject matter, applicable to all types of schools and colleges of engineering, seems to be possible. However, it might be worth while to experiment with a system of ethics erected upon analysis and understanding the natural dignity of men "endowed by their Creator with unalienable rights," which rights are inherent in that dignity. It might be possible to study the status of men in society and how they must act toward each other in order to survive and to prosper; it might be possible to explore the writings of Thomas Jefferson, Benjamin Franklin, and other stalwart intellectuals and political economists of early America, and of the great philosophers who have been recognized through the ages as the teachers of mankind; and the results and conclusions of these researches might be constituted into a norm or standard of ethics.

And when the norm or standard has been established a set of notes or a text or other suitable teaching material might be built upon the foundation of these standards; it is probably no more difficult to organize course material in ethics than in economics, politics or sociology.

In the preparation of subject matter for instruction in ethics, familiar principles of pedagogy will apply even more than in scientific-technological courses. Abstractions will be futile. Teaching must be fortified by abundant and graphic illustrations. Such, for instance, are cases of violation which come before the committees on professional ethics of the national engineering societies and before the various state boards of engineering examiners. The instructors might very well obtain from the committees and boards the records of such cases, without the names of the persons involved, and discuss and explain these cases in order to bring home to the students the practical significance of ethical standards or norms.

Conclusion

The over-all responsibility of administrative officers of schools and col-

* Journal of Engineering Education, Vol. 34, May, 1944, p. 596.

† *Ibid.*, p. 596.

leges obviously is to accomplish the purposes of engineering education. But this responsibility cannot be fulfilled by attention merely to major policies and important trends and movements. As a matter of fact, the average administrator is forced to devote the greater portion of his time, thought and effort to the solution of current problems altogether within his own institution or institutional unit, and not the least of these internal problems is that of maintaining an effective faculty. Day by day and year after year the administrator must look to the work, organization, attitude and morale of his faculty, and to the selection, promotion and general status of its members.

Administrative officers may quite as appropriately seek assistance from the Division of Administrative Officers for the solution of these internal problems as they obtain from the Division information concerning trends and developments in the profession and in the nation at large.

This report is submitted to the Executive Committee of the Division of Administrative Officers of Engineering Colleges in the hope that it may at least suggest to operating officers certain possible solutions of long standing problems of faculty administration.

J. R. KILLIAN, JR.,
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Ground School and Engineering School: Some Notes on Training

By GEORGE DUMAS STOUT
Washington University

The Army Air Forces training program involved in the almost incredible expansion of the Air Forces during the late war was one of the great experiments in mass education—an experiment conducted under circumstances that did not permit leisurely trial and error. Mistakes were made, of course, many of them; many features could have been improved and were in the course of improvement when the imminent end of the war brought the program to a close. But that the program did in the main accomplish what it was intended to accomplish is apparent in the event. Now the question is, How may that experience contribute to the improvement of our civilian education? It may help to answer that question if those of us who have recently participated in it and are now returned to civilian teaching set down, even though roughly and without too carefully thinking them through, some of the ideas and observations carried away from our recent experience.

My own contact with the program was in the ground training section of an advanced flying school. In the Ground School the cadets studied such subjects as navigation, weather, aero-equipment, and recognition of friendly and enemy aircraft, as a complement to their strictly flying training at the hands of their flying instructors. One fact that we had constantly to remind ourselves of was that we were not providing education in the broader sense at all; that the program had the strictly limited objective of making the best possible pilot in the shortest possible time; and that every effort had to be concentrated to that one end. Only by indirection and (we hoped) by example were we even trying to train our cadets to be officers. Another limitation (and it is important in studying our methods) was that the training schedule was such that the cadets could be expected to do little or no preparation outside of the classroom. That meant, of course, that great stress had to be laid on the most simple and elementary clarity of presentation, the more necessary since the cadets were more heterogeneous than even an engineering freshman class, ranging from high school graduates to Ph.D.'s in mathematics. Finally, it was mass training. Although the size of our sections was held by regulation to thirty cadets, that was the minimum as well as the maximum, a fact which precluded any individual or small-group training, and which precluded anything remotely resembling laboratory work. Actually, of course, the cadets' laboratory was the flying line, where frequently their lives were at stake; one of the great needs of the program, on

which we were working at the end of the war, was the closest possible cooperation between Ground School and Line.

Part at least of the extraordinary improvement in ground training during the years 1942–45 came, I am convinced, from the very fact that both instructors and supervisors realized more and more acutely the necessity for sharp limitation and definition of objective. By knowing with greater and greater definiteness what we had to do, we were able to make more and more effective plans for doing it. It is a lesson that may well carry over into civilian education. My own courses in engineering school have been in the field of English, and there I know we should profit by a sharper definition of objective. Is our job merely to train the novice engineer to use reasonably grammatical and, within practical tolerances, effective language in his technical reports? Is it to give him some sense of the current world outside of his technical interests so that he can read the editorial page of the newspaper intelligently? Is it to acquaint him with some of the traditional values in the literature of the past as well as of the present? Is it to give him confidence in speaking before an audience of his peers? Or is it some combination of these and perhaps others? These questions could be the subject for long debate with probably various conclusions. But if some definite answer be arrived at, then the instructor can make his plans and bend his energies with a good chance of arriving at the predetermined goal. As the situation now stands, the objective sometimes seems, like the velocity and position of the electron, to be determined in accordance with some principle of uncertainty.

I have spoken here only of English; but my engineering colleagues will forgive me if I suggest that something of the same uncertainty may possibly exist in some of the more technical courses as well.

To turn now to rather more concrete matters. Since the training of our cadets was severely practical and factual, every possible use was made of training aids. These fell roughly into four classes: first, charts, including maps, posters, and all kinds of previously prepared visual material; second, projected material, such as training films, film strips, slides, etc.; third, specimen parts and equipment, either complete or cut away; and, fourth, mock-ups and synthetic devices.

Of these four, charts were the unspectacular but indispensable workhorses of the program. Their adaptability to an infinite variety of subject matters and uses, their general availability, the comparative ease and cheapness of preparing them, the lack of any necessity for elaborate equipment to use them in the classroom, and, finally and most important, their invaluable contribution to a lucid and simple explanation of a structure or an operation —all these factors made them a "must" for almost every class. They could range from (say) large outline maps covered with pliofilm on which weather symbols showing changes from day to day could be marked with grease pencil to (say) permanent representations in color of the formation of carburetor ice; they could present statistical graphs showing proper power settings under varying conditions, or they could show the flow of fluid through a complicated hydraulic system. Many thousands of them were prepared and distributed through such central agencies as the Ground Training Technical Advisory

Department and many thousands more were available from the manufacturers of air equipment; but frequently as valuable, as being even better adapted to the local situation, were those locally prepared. Every ground school I knew kept at least one draftsman busy making them at the request and specification of the instructors.

As for their use in the classroom, there are, of course, a few obvious precautions. A chart to be effective must be large enough and simple—I repeat for emphasis, simple—enough to be seen and understood in the farthest corner of the room. In other words, it should be designed for the primary purpose of teaching, and not, as too often, be merely a blown up version of a working drawing, with needless and confusing complication of detail and legend. For the same reason, it should be in bold outline and in bold colors. It should be suitably displayed, preferably on a special stand, built to show one chart, and one only, at a time, in proper sequence. As a matter of fact, the charts covering a given section of course should be bound together for convenience in filing and handling.

The use of projected material, such as training films and film strips, naturally involves much more elaborate equipment; and at once the problem of the budget raises its ugly head. Furthermore, I am convinced that, since such aids are the more effective the more closely they are integrated with the other elements of the course of which they are a part, they should, if it is at all possible, be shown in the same classroom or laboratory in which the other work is being carried on. The problem of the projector is not too great: sixteen millimeter equipment is reasonably portable. But the room itself needs special preparation: it should be dark enough for clear projection and yet not too dark for note taking and good classroom discipline. Since windows have to be at least dimmed out, some form of air conditioning is necessary if class and instructor are not literally to stew in their own juices during warm weather. In our ground school the problem was solved by equipping two classrooms with a primitive form of evaporation air conditioner (effective in that dry climate) and scheduling in those two rooms the courses that required extensive use of projected material. The other classes simply had to suffer in their dimmed but un-conditioned rooms. Although it would greatly complicate the scheduling, possibly some such solution could be worked out by an engineering school. Certainly if a class has to be moved to a special room every time a projector is to be used, much valuable material that would take only part of a class hour for presentation becomes for all practical purposes unavailable.

Of the material to be so presented the training film is perhaps the most interesting. Ranging in length from the short of five or ten minutes to the full length of forty minutes or more, complete with sound track, sometimes with animated diagrams of a distinct Disney character (as a matter of fact, Mr. Disney did have a hand in making a good many of them), many of them were superbly informative. They too improved enormously during the years of the training program. The early ones were factually sound enough but apt to be poorly planned and dull; when Hollywood, with its expert knowledge of audience reaction, took a hand in their production, they began to combine factual accuracy with a liveliness of presentation that surpassed in

interest all but the most skillful of conventional classroom instruction.

And in that very fact lies one of the dangers of a too enthusiastic adoption of the training film into our courses. As a teaching aid it is invaluable, but its position as an aid and only an aid must never be lost sight of. The modest, as well as the indolent, instructor may be tempted to think that, since the film covers the subject more vividly than he can hope to, all he needs to do is arrange for its showing. But that is far from enough. The more graphic a film is, the more likely will the student be to sink back into unthinking enjoyment: a situation sternly to be guarded against. The instructor must himself know explicitly what he expects his students to learn from the film, he must make clear to them in advance what he expects them to learn, and he must test them to see that they have learned it. Only then will the film be a truly integral part of the design of the course.

Not all of the films used in the ground schools were especially produced by and for the Army. Manufacturers of air equipment (for instance the Wright Corporation with their "Cyclone Combustion") have made a number of films, technically excellent and without egregious advertising, which were officially sponsored in the training program. They should be a rich source for use by engineering schools.

The film strip, although not so immediately interesting as the training film and not so extensively used in our ground school, is perhaps even better adapted to day in and day out classroom use. It is a series of stills covering a structure or an operation in proper sequence, with the necessary captions interspersed, on continuous 35 mm. film. Its principal advantage over the moving picture (aside, of course, from the obvious ones of being cheaper and requiring a much less elaborate projector) is that it is more flexible, more easily adapted to the particular instructor's scheme of instruction. It is closely comparable to the oldfashioned series of slides, but is more compact and considerably more easily manipulated.

Simply to make the tale of our projection equipment complete, I should mention two other devices: the balopticon and the flash shutter. The former we used a good deal to project cuts, diagrams, tables, and other printed matter, which seemed desirable to bring before a whole class but not valuable enough to be processed as charts or slides. The other device was the flash shutter fitted on a standard slide projector, so that the image could be flashed on the screen for a fraction (usually $\frac{1}{25}$ or $\frac{1}{50}$, although occasionally $\frac{1}{100}$) of a second. This was used in training the cadets to recognize friendly and hostile aircraft; it is a highly specialized device for which it seems unlikely that there would be much, if any, use in civilian training.

On the whole the ground school probably used specimen parts and equipment considerably less than the normal engineering school, particularly since, as I pointed out earlier, we made no attempt to do anything resembling laboratory work. Only one point of interest should perhaps be noted: the extensive use of plexiglas in preparing such parts for classroom demonstration. Since plexiglas is thermoplastic at a relatively low temperature, it is easy to mold it into shape and substitute it for a regular metal or other opaque cover. For instance, a set of flight instruments in working order

can be put into plexi cases and, since the pressures under which they operate are low, can be shown in actual operation. At Air Force installations having elaborate facilities, complicated, large-scale working models were sometimes constructed of this transparent material, sometimes in various colors; their usefulness for demonstration purposes was very great. But even where such de luxe equipment was not feasible, the employment of plexi frequently made it possible to protect a delicate part from dirt and from prying fingers, and at the same time display it clearly.

Probably the most spectacular and widely advertised of the training aids were the various types of mock-ups and synthetic devices. But I do not propose to discuss them at any length here, partly because they do not differ in principle from the laboratory and shop equipment in any good engineering school, and partly because their extraordinary range and diversity make any general statement almost impossible. Among them were certain standard devices, such as the well-known Link Trainer for teaching the cadets to fly on instruments. But beyond these they were limited only by the ingenuity and inventiveness of the instruction officers and by the facilities available for their construction. At one school for training aviation mechanics, for example, there was an airplane cockpit complete with engine and propeller controls and instruments, so wired through a maze of electrical connections and rheostats that any manipulation of the controls would produce the proper response on the proper instrument or instruments. At the same school a Hamilton Hydramatic propeller cut-away, which obviously could not function under its own hydraulic power, had been ingeniously rigged to operate by electricity so that its complete cycle of operation could be shown. Again, such elaborate devices were not found in the majority of ground schools, but we all had our programs for developing mock-ups, etc., to meet our particular needs and within the range of our capabilities. And that is probably the situation of any engineering school.

There is, however, one general suggestion growing out of my experience with these training aids that I should like to make—although with some hesitation, since it may already be standard practice. That is, that in every school, or in every department if the school is large enough, there be one member of the staff whose primary duty, or preferably whose whole and sole duty, be the development and procurement, the maintenance, and the distribution to the point of use, of these training aids. Furthermore he should have under him a staff and a shop as large and elaborate as is consistent with the budget and the policy of the school. He should be a man of great energy and great ingenuity; he should be able to take a half-formed idea for a mock-up from an instructor, develop it and make it concrete, and then, out of such odds and ends of material as he can pick up, build it. He should maintain a film library, by purchase and by rental, and should be constantly on the alert to discover new film material. He should keep the charts for use in each course filed so that they are immediately available in the proper sequence. He should have draftsmen and keep them busy turning out not only the necessary working drawings but also new and better charts as in-

structors ask for them. Such a man, with adequate staff and equipment, not only would relieve the individual instructors of a burden which they cannot properly shoulder, but by being able to focus all his energies on the training aids program should be able to produce more effective results. Moreover, by centralizing the development and control of these physical aids, he should, under the normal shortage of money and equipment, be able to make more efficient use of such equipment as there may be than if its control were scattered among half a dozen or more normally individualistic instructors.

This paper does not defend a thesis, it does not come to any conclusion; and having exhausted my allotted space I must simply stop. As the title indicates, it is merely "some notes," my first hesitating attempt to collect and sort out the observations of the past three years. To me some of them seem significant, perhaps even helpful in achieving the ends of education. I can only hope that they may seem so to others.

ERRATUM

The authors of "The Blueprint Language of the Machine Industries" are Henry C. Spencer and H. E. Grant and not Henry C. Sherman and H. E. Grant as stated on page 3 of the May issue.

Patent Policies for Sponsored Research*

By RALPH A. MORGEN

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During the past decade there has been a noticeable trend towards the sponsorship of research by industrial concerns at the various universities. It is believed that in the next few years that trend will be accelerated. Since universities in general, and tax supported institutions in particular, have a responsibility to the public, the question of patent rights in connection with sponsored research becomes a very important problem.

In order to formulate a sound policy for the University of Florida a study was made of the policies of other universities. Forty-two replies were received to a questionnaire, and based on these a policy was formulated for the University of Florida. That policy was expressed in the resolution quoted below and adopted by the Board of Control for the University of Florida on October 12, 1945:

WHEREAS, the University of Florida, a state-supported institution for higher education, has a responsibility and interest in the advancement of scientific knowledge, and in the advancement of the economic interest and welfare of the people, particularly the people of the State of Florida, and

WHEREAS, this responsibility and interest can from time to time be advanced by engaging in research, the results of which may have commercial applications which are patentable and should be patented in the interest of the public, and the income from which may be used for the promotion of further scientific research, and

WHEREAS, such research in some instances is cooperative in character, financially and otherwise, with outside persons and organizations, and

WHEREAS, such research undertaken at the University involves the use of staff and facilities not always accurately measurable in dollars,

Now, therefore, The Board of Control, acting for the University of Florida in an effort to promote such research for the advancement of science and the economic and social welfare of the people, indicates its willingness to undertake such research in cooperation with outside persons and organizations within the limitations of its staff and facilities under the following general conditions:

1. That unless otherwise provided in the agreement patents shall be controlled by the University.
2. That the University will be willing to consider the granting of a non-exclusive license (shop-rights) without further cost to the cooperating person or organization which provides funds for the direct and operating overhead costs of the research.
3. That if the research undertaken by the University is a continuation of research already initiated by the cooperating person or organization, if the research results of the University require further development work for commercial application, or if for other

* Presented at the meeting of the Southeastern Section, S.P.E.E., Vanderbilt University, April 26–27, 1946.

reasons the public interest can thus be better served, the University will be willing to consider the granting of exclusive licenses on payment of a suitable royalty. In special cases the cooperating person or organization may acquire partial or complete ownership of patents resulting from such research provided the University receives full reimbursement for all costs. In the case of complete ownership of patents by the cooperating person or organization an additional patents charge shall be made.

TABLE I

ANALYSIS OF UNIVERSITY PATENT POLICIES ON SPONSORED RESEARCH

	Multiple Choice Contracts	Single Contract	Free License to Sponsor	More than Free License, Less than Full Ownership to Sponsor	Ownership of Patent to Sponsor
Alabama, Univ. of	x		x	x	x
Carnegie Institute	x		x	x	x
Colorado, Univ. of	x		x	x	x
Delaware, Univ. of	x			x	x
Florida, Univ. of	x		x	x	x
Georgia School of Tech.	x			x	x
Illinois, Univ. of		x	x		
Iowa State College	x		x	x	
Kansas State College	x		x		x
Louisiana State Univ.	x		x	x	x
Louisville, Univ. of		x			x
Maine, Univ. of	x		x	x	x
Mass. Inst. Tech.	x		x	x	
Michigan State College	x		x	x	x
Michigan, Univ. of	x		x		x
Minnesota, Univ. of	x		x	x	
Nebraska, Univ. of	x		x		x
N. Y. Col. of Ceramics		x			x
N. Y. Univ.	x		x		x
Ohio State Univ.	x		x	x	x
Oklahoma A. & M. College		x			x
Penn. State College	x		x	x	x
Purdue Univ.	x		x	x	
Rhode Island State Col.	x		x	x	x
Rochester University	x		x	x	
Stanford University	x			x	x
Tennessee, Univ. of	x			x	x
Texas, A. & M. Col. of	x		x	x	
Texas, Univ. of	x		x		x
Toledo, Univ. of	x		x	x	x
Utah, Univ. of	x		x	x	
Virginia Polytechnic Inst.	x			x	x
Washington State Col.	x		x		x
Totals	29	4	25	23	25

Nine universities reported that their policy is now in process of formulation. Those universities are: Alabama Polytechnic Institute, Cornell University, University of Kentucky, University of Maryland, University of New Mexico, North Carolina State College, Oregon State College, West Virginia, and the University of Washington.

It is clearly recognized that a rigid patent policy cannot fit all cases. A standard contract form was prepared to implement the resolution which permits the sponsor to choose one of four patent options. In the first case the sponsor is interested only in basic information and all patent rights belong to the University. The sponsor pays only for actual salaries and materials used. He pays no overhead charges and merely gets a report of the findings in advance of publication. If patentable information is obtained he would have the advantage of obtaining an early favorable license.

In the second case the sponsor pays a flat sum to cover estimated expenses plus an overhead charge of thirty to fifty per cent on the estimated salaries depending on the nature of the problem. The University pays for and obtains any patents which might result from the work. The sponsor receives a free, non-exclusive, non-transferable license under such patents without further charge.

In the third case the sponsor, because of his activity and ownership of related patents in the field of investigation, may obtain ownership of the patents resulting from the research. However in addition to paying all direct charges and full overhead of fifty per cent on salaries, he must pay a flat fee at the time of signing the contract for this patent privilège whether or not any patentable information is obtained.

The fourth case is an intermediate one between the second and third types. The sponsor could obtain more than a free license, such as an exclusive license for five years, with ownership of the patent remaining with the University. In certain special cases the sponsor could obtain a percentage ownership in the patents with participation in royalties paid by other users. Each case of this kind must be considered on its merits and the amount paid by the sponsor would be in proportion to the benefits he would get when and if patents resulted from the research.

That this policy is in accord with most universities which have a definite patent policy on sponsored research is demonstrated in Table I. Of the thirty-three universities reporting a definite policy, twenty-nine (88 per cent) have a flexible policy permitting more than one patent option. Of the four with a single patent policy three give ownership of the patent and all rights to the sponsor. Twenty-five (76 per cent) of the universities permit the sponsor to obtain ownership of the patent under special considerations. All of the universities permit the sponsor to obtain at least a free non-exclusive license under the patents and thirty-two (97 per cent) allow him to obtain more than a free non-exclusive license. The great majority have a definite policy of balancing protection which is due the sponsor for his foresight in initiating the work against public responsibility and the good of the people as a whole.

I Think———

By BENJ. F. BAILEY
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To become "educated" is a long and difficult process. It starts in the cradle and ends only at the grave. This education is mainly along three lines: a certain number of facts must be memorized, the ability to live in harmony with others must be acquired, and lastly it is at least highly desirable that the ability to think be developed as far as is possible. Even a dog makes some progress in the first two lines. He learns certain facts, for example, the location of certain garbage pails, and he makes some progress in what the schools call good citizenship, *i.e.*, certain actions lead to unpleasant consequences. But he never learns to think, that is to reason.

In the education of a child it is obvious that he must acquire a certain amount of factual information. He must learn to speak the language of his country and to read and write it fairly well. He must learn something about geography and at least enough arithmetic to make change. All this factual information can be acquired with very little use of the reasoning powers.

The second phase of a child's education has to do with developing his ability to get along with others. As soon as two or more people must live in intimate contact with one another it becomes necessary for them to learn to defer to the opinions and wishes of others to a reasonable extent. In our own families some of us learn to avoid trouble but by no means all of us. Among our business associates we do much better. If we don't like the ties our boss wears we say nothing, but at home, it is another matter. If we were as polite to our families as we are to our friends much trouble would be avoided.

Our most conspicuous failure is in our inability to get along with people of other nationalities. Perhaps they speak a strange language, or perhaps they have oil wells while we haven't. Or perhaps they believe all men should share equally in the good things of life while we believe the smarter, the stronger and the more industrious should have a greater share. Perhaps some of us believe the black man should work for the white man, while others do not at all agree. Up to now the only way we have found to settle such matters is to slug it out until one side gives up. Perhaps we have devised a new way in the UN; at least let us hope so.

The third step in becoming educated is to learn to think, perhaps I should say to learn to think logically and correctly. The dictionary says, to think is (1) to exercise the mind; (2) to revolve ideas in the mind; (3) to form or hold as an opinion; (4) to consider: to purpose or design: to imagine: to judge: to believe or consider. I suppose everyone thinks as defined under (1), and most of us "revolve ideas" in the mind (*e.g.* I think I will ask my girl for a date). The kind of thinking

implied under (3) is one of the curses of the world. A child born in Mississippi grows up to "think" the Democratic party is far superior to the Republican while one born in Vermont holds just the opposite opinion. The child born in certain parts of Quebec grows up a Catholic and is prepared to die for his beliefs if necessary; others grow up believing that all Catholics are in a plot to destroy the country. Some go through life "thinking" that all serpents must crawl upon the ground because one serpent in the dim past tempted Eve, and some of our revered ancestors harried poor old women to their deaths on account of one isolated sentence in the Bible (Thou shalt not suffer a witch to live). Does anyone believe for an instant that all these fixed ideas are the result of logical thinking? One is forced to the conclusion that the great majority of people cannot or at least do not reason about such matters. Our most passionate beliefs are merely what someone told us when we were young.

Occasionally a real thinker is born and shines out like a beam of light from a light house on a black night. Too often his light is obscured by the fog of prejudice and superstition by which he is surrounded and reaches only a few feet into the fog. To be such a man used to be dangerous. Christ and other religious leaders were persecuted and even lost their lives. Bruno was burned at the stake and Galileo barely saved his life. One incident in his life illustrates well what I am trying to say. Plato who was a thinker along certain lines made the statement more than 2,000 years ago that the speed of falling bodies is proportional to their weight and for about 1,500 years nobody doubted this statement. Five minutes time and a couple of stones would have served to prove its falsity. Even a few minutes real thought would have given the correct answer but for many years no one threw the stones or gave the matter real thought, and when Galileo offered to show the philosophers of his time by dropping weights from the leaning tower of Pisa, they refused even to look. We are apparently more open minded today (at least about the laws of nature) but we still find people who insist that the world is flat and not long ago a book was printed in which the author proves to his own satisfaction that the world is really a hollow ball and that we live on the inside!

Learning to Think

That it is desirable to be able to think straight requires no argument. It is true that many people live happy and prosperous lives who have never acquired this ability (some even become governors of states or United States senators) but there are situations in which some straight thinking is essential. Most engineers, if they are to rise to the top of their profession must solve problems which require the ability to add two and two together and get four every time. In professions such as law, medicine and teaching, industry and a good memory will carry one a long way but even here some real logical thinking is very useful.

Assuming that it is desirable to be able to think, how can this ability be acquired? In my opinion the first requisite is to be born that way. Consider Benjamin Franklin. With practically no formal education but with an insatiable curiosity about the things he saw around him, he thought things through. On his first voyage to England he used some of his spare time

measuring the temperature of the sea water so he could plot part of the course of the Gulf Stream. Simple enough but apparently no one else had thought to do it. On a canal boat in Holland the boat men said it was harder to pull a boat in shallow than in deep water. Most people "think" this is silly, but Franklin thought it out and immediately wrote out the correct theory. Largely to convince others, since this was an important matter in those days of canal boat travel, he seized the first opportunity to construct an experimental tank in which he could test small models of boats. Another case of simple but straight thinking. Consider his bifocal lenses for spectacles, water tight bulkheads for ships, the Franklin stove and many other inventions. Simple things all; anyone could have thought of them, but no one else did.

Thomas Edison was another self-taught genius. Certainly no one taught him to think; if anything many people tried to prevent him from thinking. Many more could be added to the list but perhaps these are enough.

Does going to school kill the ability to think? Certainly not, though some teachers may try to stifle all free thought. Thompson, Steinmetz, Langmuir, Coolidge come to mind at once and hundreds of other names could be added to the list. They were all highly educated men but certainly no one would deny that they were thinkers.

All these facts indicate that the *ability* to think is a God given gift but it is still true that much may be done to encourage the *habit* of thought. The home environment is doubtless far more important than the school, and wise parents may do a great deal to encourage the child to think things out for himself. One way to do this is to answer fully and frankly all the innumerable questions the child is continually asking. This is not always easy. Why are you a Democrat, father? Why is uncle Ed a Catholic? Why do the other boys chase the Jewish boys?

I appreciate the difficulties involved in answering such questions. Many, perhaps most, parents lack the ability to take an impartial attitude in matters of say religion or politics and if the discussion gets at all hot fall back upon the unanswerable argument, "I know better than you and it is so because I say so." In the matter of religion many people believe in teaching the young what they consider to be the truth simply because that is what they learned when they were young. The fact that countless millions believe something entirely different does not disturb them in the least. They know the truth; any other beliefs are a snare of the devil. If a parent has a mind of this calibre, he had better avoid the subject entirely.

In his school life, what studies serve best to develop the habit of thought? The first to be encountered is arithmetic. Certainly here the student is compelled, probably for the first time, to think logically. This is particularly true if the problems are well selected. Other elementary studies such as spelling, language study, and geography require little more than memory. My study of Latin was valuable since for the first time, I was forced to study hard, but it did nothing to teach me to reason. Algebra required some thinking but mainly the ability to remember and apply rules. Geometry was a revelation to me. Here was pure reason with very little memory involved. For the first time I did not need to believe something because someone else

had said it was true. I had only to think for myself.

The study of Physics and to a lesser degree Chemistry requires clear thinking. Analytic Geometry, Calculus and Descriptive Geometry should be included in the list. I should also like to have every student required to take at least one course in Economics. Here is a subject involving a different kind of thinking. In Geometry if 100 different people study a problem and all reason correctly, all will arrive at the same answer. Not so in Economics as we all know to our sorrow. However a little clear thinking will lead to agreement on many points which are today in dispute. Philosophy is another thought providing subject and one who wants to take a broad view of life cannot afford to neglect astronomy. It compels thought of still a different kind.

Let us assume that in due time the student has progressed to junior or senior standing in an engineering college. What can be done to encourage him to reason correctly along engineering lines? In the first place I would strongly urge that much now included be omitted but that the fundamentals of each subject be hammered home until they become a real part of the student's mental equipment.

Here are a few illustrations of what I mean. If you ask a class of senior electrical engineering students the time relation between the current and the flux in an alternating current circuit, you will find that more than half of them think the flux lags 90 degrees. If you inquire whether or not distance from the coil makes any difference, they are surprised and confused even though all of them know something about radio. In an examination a student once filled several pages with formulae and diagrams relating to alternating current transformers. The paper was perfect—not a mistake in it. But a casual conversation with the student after the examination brought out the fact that he thought a transformer would work equally well on direct current!

How many of your students are familiar with the fundamental fact that the influence of anything concentrated in a point (*e.g.* gravity, light, electrostatic effect, etc.) varies inversely as the square of the distance, in a long line, inversely as the first power; and in an infinite surface, as the zero power. It would be easy to multiply examples but every teacher can supply many from his own experience. Facts such as these must be firmly fixed in the student's mind before he can begin to reason from them.

As previously indicated I somewhat doubt the possibility of teaching any one to reason. To some it is instinctive, others can remember but utterly fail to reason.

If one stops to think it is really surprising how seldom we are forced to use our reasoning powers in everyday life. One man may go through life firmly believing that the world just as we know it today was created in six of our days, and be highly successful, financially and socially, while his friend who thinks we have evolved to our present status may be an abject failure. Indeed if his thinking leads him to beliefs, different from those of his neighbors, he is likely to get into serious trouble. Only 300 years ago in Massachusetts a man who believed that there were no witches was likely to lose his life, and if he lived in Europe and reasoned that the world was round, he might be burned at the stake.

However, most of us would agree

that it is a good thing (especially for an engineer) to be able to "think straight," even though we could be quite comfortable without this ability, and if a boy can reason correctly he should be encouraged to do so. The following are some of the ways in which the teacher can help him.

Try to get the student to question everything he sees, hears and reads. Ask a class to list the defects of the desks they are using. This is easy. Can they suggest improvements? Not so easy. Are the suggested improvements practicable? If not, why not? Why is the engine in an automobile usually in front? Why not in the rear? What advantage has a big ship over a small one? An engineer who gets into the habit of thinking that everything is wrong (or at least that it could be improved) is likely to come up with something of revolutionary importance.

Get some sketches of "perpetual motion" machines and ask each student to prove just why they will not work. Call his attention to a leather belt transmitting power. One side is tight and it stretches and its cross section is reduced. Since both sides move at the same speed, more leather is coming off the driving pulley than is going on to it. How come? Some bright students will see the answer and will forever afterward know that a belt must slip. All right, but how about the driving chain of a bicycle? Can it slip? Does it not stretch?

Here are some more "trick" questions, largely from my own field of work. What happens when a series d.-c. generator furnishes current to a shunt wound motor? To a separately excited motor? To a similar series motor? Compare the characteristics of a polyphase induction motor on normal voltage and on 10 per cent lower voltage. On 60 and on 50 cycles. What is the objection in a d.-c. motor to having the armature stationary and the field rotating? How about putting the field inside the armature? (I remember seeing large machines built that way in my youth.) What is the inherent reason why the constant current system was doomed to failure, while the constant potential system was successful? State some of the reasons why direct current transmission is superior to three-phase transmission. Why is it not used?

Of course the answer to these proposals is that there is not enough time, but if training of this kind is worthwhile, we must make time. Perhaps some of the time spent making pretty curves for laboratory reports might better be spent in serious thought on some of the fundamentals. Let us have more time devoted to things which the student will use all through his career and less to facts which are better preserved in a hand book. If we can turn out graduates who have developed the habit of thought, who will not accept a statement just because someone said it was true we shall have made real progress toward a better world.

Selective Service*

By M. H. TRYTTEN

Director, Office of Scientific Personnel of National Research Council

Selective Service is a present in a state of flux. Those of us who are working with it in Washington have a feeling that things have materially changed during the past few weeks.

Certain things make us feel that way. There are a few concrete things that I can report on this morning, such as the Selective Service release of last week and an Army release which I expect to tell you about a little later; an agreement for the release of scientific and technical personnel in the Navy which is not so far along that I can say definitely that it will be issued, although I am quite confident that it will; and particularly the fact that this change has come about in the way it has come about has convinced us that we are now at a time when the attitude on this whole matter in the Administration has sharply changed.

I think probably I can give you the feel of the situation a little better by going back just a little bit in the history of the Selective Service during wartime and recalling to you certain things. I think of the Selective Service wartime picture as being divided into a number of periods, so to speak.

The first period, I think, ended with the midsummer of 1942, or about August of 1942. Before that time there was a period during which the agencies and the organizations in Washington who were concerned with high grade manpower, such as American Council of Education, the Roster, the Research Council, and other groups, were trying to get established, shall we say, the proper Federal policies in this field, and I think some of you must be very familiar with that period, because you took part in deliberations at that time.

You will recall that the American Council set up two committees, advisory to the various Federal agencies and advisory to the headquarters of ACE. The National Headquarters of Selective Service also brought to Washington an advisory committee, the War Department had an advisory committee, and so on. As a result of these deliberations there were a number of things proposed in Washington, all of which were quite similar in basic concept.

The showdown, however, came in about August of 1942, and the showdown was before a committee which met, I think, mostly behind closed doors, a committee representative of a very few of the top agencies having to do with the war, such as Army and the Navy, the War Production Board, the War Manpower Commission, and so on. This small committee came out with a statement of policy which is the tip-off on the policy which occurred from then on to the end of the war.

The major part of the policy was aimed at students, that is, the handling of training in these fields, and its central

* Presented at a meeting of the Division of Administrative Officers of Engineering Colleges at Pittsburgh, Pa., December 7–8, 1945.

core statement (I shan't go into details on the statement at all, I just want to touch on some of these things lightly) was that it was the destiny of every able-bodied student to go into the Armed Forces eventually. That was stated specifically in this resolution. Following that, the policy stated that it was therefore the responsibility of the Army and Navy alone to deal with their training.

Now in spite of the fact that this dealt only with training, I think it is fair to say that it represented practically a basic policy with the Government from then on; that is, it was their general feeling that it was the destiny of every able-bodied American to wind up eventually in the Armed Forces. In other words, it was a complete negation of the principle that some people serve better in one way and some serve better in another way; in other words, a complete negation of what we think is a very fundamental principle, the principle of maximum utility of each person.

In the carrying out of that, the effects were not immediately apparent, because Selective Service had not gotten to the point where they were scraping the bottom of the barrel so assiduously as they did later on. The first effect of these policies came about in the fall of 1943 when the National Committees in the scientific fields were abolished. Then in January of 1944, you recall that the deferments of college students were restricted to a quota basis, totaling about 10,000, and these were in turn cancelled in late spring. Then later in 1944 the decision was made to stop the deferment of all able-bodied men under 26 years of age.

From then on the policy bumped along the bottom. A story that illustrates the Selective Service situation at this time is one that occurred to me in June of 1944.

After the Selective Service decision was announced, that deferments were to be confined to those over 26, the effect of that of course became clear to people dealing with war research and they realized that something immediate would have to be done to counteract it. Dr. Vannevar Bush became concerned, and a number of other interests took action in the hope of getting the decision at least held up temporarily until some clearer policy could be adopted. During this period of confusion, May and June of 1944, there was a period of about three weeks during which the intervention of the Office of Scientific Personnel was used as an informal interim means of securing stays of induction in cases where induction seemed to be clearly against the public interest.

It was necessary for me then to take these cases over to Selective Service and present the cases individually to the proper persons, sometimes a score being presented each day. I remember one case particularly, a young man who was an engineer and scientist in the mining field and was a key person in the mining of molybdenum. He was a very important man indeed to the employer. I investigated the case and found that it seemed very important, in fact, a critical case. So I presented the case to the officer in charge, discussed it with him. He said he would take it home and think about it and make up his mind by morning. A telegram would have to be sent by 8:00 o'clock in the morning to stop induction.

So when I was over there the next day, I asked him about it, "What did you do?" He said, "I stopped induction." He smiled and said, "You know, at dinner I was thinking about

this case and I asked my son, 'What is molybdenum,' and the boy said, 'That is a heavy metal.' Right away it occurred to me that maybe this was connected with the Manhattan District in some way, and so I went back and wired to have that induction cancelled."

"Now I submit that when the handling of a key scientist or engineer has to depend on the interpretation of what a high school boy says about his chemistry course across the dinner table, the policy is not in safest hands.

I give you these reminiscences with a purpose. There is a very definite reason why policies in regard to manpower in the highly specialized fields were not wisely drawn. Such policies can only be drawn by men who know the subject well. But in a time of war the controlling element must necessarily be those responsible for the conduct of the war. The men in charge at the front become the dominant influence perforce and rightly. Their concepts are naturally heavily weighted by front line needs and less responsive to the needs of the rear and indeed to the necessities of the future of their own forces. So such erudite things as the proper utilization of specialists become inaudible in the background noise. Only if policies, arising in the quiet and calm thoughtfulness of more peaceful eras, are ready to stand in a period of stress will these needs be served. There is evidence that this problem will be back to plague us.

Nevertheless, the educational campaign put on by the various technical organizations to acquaint the Government with the needs of the nation in regard to utilization of scientific and other highly trained personnel were not wasted. Many persons in the Government and Congress have been made aware of the necessity of a rescrutiny of our official policies as soon as possible.

I think the effects of this educational campaign first became apparent to those of us who were working with this problem immediately after V-J Day. At that time the new Director for War Mobilization and Reconversion was appointed, Mr. John Snyder, taking office in August of 1945. Mr. Snyder's attitude was very enlightened. On August 27 he called representatives of the American Council of Education in his office to discuss a bulletin put out by the American Council and by the Office of Scientific Personnel in which the manpower problem was treated. Mr. Snyder indicated an interest in concrete proposals for dealing with the problem. Certain proposals were submitted by the American Council on Education confined particularly to resumption of training. A letter from the Director of the OSP was likewise submitted, pointing out the necessity of revising Selective Service regulations to stop the induction of key people important to reconversion and to the welfare of the nation and to secure release from the Armed Services of highly trained personnel.

Early in September a meeting was called by Mr. Snyder's staff to consider these appeals. No specific action was taken at that time but it seemed apparent that changes in policy were imminent.

However, the realization of these changes in regulations was not rapid, although progress seemed definite.

During this time it is interesting that much attention to the problem was given in cabinet meetings. Reports indicate that Secretary of Commerce Wallace was particularly interested and

recommended to the Cabinet that the problem be met promptly.

Selective Service has finally issued a new release embodying some of the reforms sought and requested by the Administration.

Local Board Memorandum 115 was issued as of last Friday, November 30, and together with it issued Local Board Memorandum 115-M in the SS 115 series. Local Board Memorandum 115-M deals particularly with students and research workers in these fields. Local Board Memorandum 115 is probably familiar to most of you and I shall not call your attention to it except to state that to secure deferments it is still necessary to use the 42-A (revised) form, which Selective Service has been issuing for some time, and by using these forms it is possible to request deferment and get consideration for individuals working in projects dealing with military matters and for key personnel in reconversion activities. According to the Director of Selective Service, that should secure adequate protection to all scientific and technical personnel in industry. This is the way the Selective Service puts it: The machinery is there to protect such personnel, and if there is an error it is an Administrative one. If it is called to their attention they will endeavor to provide that it is rectified.

I take this to mean that if anything goes wrong in an individual case, it should be brought to their attention and they will take the necessary action. I was concerned with about five individuals last week, two of them up for induction on November 30, the date the new order came out, and I suggested that the employers wire full information to the appropriate officer of Selective Service on the Morning of November 30. They did, and the induction was stopped in those two cases. So there is some indication that action can be taken in such cases.

With regard to 115-M, there are two things I want to call attention to. One of them is that the Memorandum permits—or rather, recommends—to the local boards that they consider seriously for deferments advanced students in the physical sciences and in engineering who have been accepted, (a) as candidates for masters and doctors degrees, that is at the graduate level, and (b) if they are seniors who have been deferred for at least two years for some type of war work.

The following procedures are indicated. The university may apply for his deferment, directly to the local board. At the same time there should be sent to the Director of War Mobilization in Washington a statement with three items involved, three documents: One of them is a notarized statement of intention of the individual, that he proposes to go ahead and continue his training; the second is a statement from the college or university that he has been accepted for this type of training; and the third one is, of course, the Selective Service information. Those things need to be sent to Washington, and there are attention by the appropriate office. Consideration will be done mostly by OSRD. The processed papers will be sent from there directly to the State Director and down to the local board. In the meantime, the request is at the local board, and it is wise to inform the local board that this procedure has been adopted and that information will be coming along through this long circuitous path from National Headquarters.

There is one other thing I want to

mention. A committee has been set up which is in a sense a policy advisory committee in this field, established in the Office of War Mobilization and Reconversion. Its purpose is to advise in manpower shortages and all actions to secure remedial measures, with regard to those fields which should be included, and what levels of personnel should be involved. It is essentially inter-agency, with representatives of OSRD, CRA, the Rubber Administration, War and Navy Departments, USES, the Office of Education, The National Roster, and the Selective Service System. As I say, it is essentially an advisory committee, but the individuals who represent the agencies on that committee are people who have shown an interest in this problem over a long time, and in particular the subcommittee which deals with the things that I have just mentioned specifically is a subcommittee of three representing OSRD, the Roster, and the Office of Education. Mr. Kelly represents the Office of Education.

So much for the Selective Service picture at the present time. You know, of course, the situation with regard to freshmen. It is possible to secure the deferment of freshmen until they have finished the term in which they became 18 years of age. The question of whether this policy will be extended to permit the students involved to continue an additional semester will have to be decided soon, I would say within a few weeks. In that connection we are trying to get some information together, to piece out our information as to what is going on on the campuses, not only in the larger institutions, but the smaller ones also, that the information will be on hand to permit an intelligent recommendation.

I stated that the War Department had come to some conclusions with regard to the release of scientific personnel. I was told Thursday afternoon late, just before I left, that the release had just come off the press, and the person I spoke to had an advance run-off, and dictated some things over the telephone to me.

The release will provide that military personnel who have been or are engaged in scientific research projects in the Army may apply for discharge under Paragraph 3 of Regulation 615-365, provided—and these are the conditions under which they can be discharged: That they hold a bachelor of science degree in physical sciences or engineering or basic sciences or engineering, and have been accepted as graduate students or as teachers or in research in accredited universities or colleges. Those people who fulfill these conditions may apply for release and presumably their request for release will go to an Army separation board, who will be inclined to grant their release under this new policy.

Furthermore, these people can be released if they have been accepted for research in the physical sciences. In this latter case, where the individual asks for release for research, the procedure is confined to physical sciences, and to those who have been accepted for a research job in the physical sciences in a reputable scientific laboratory. That is the wording used in that release. The request must of course have documentary evidence to show these things. And too, that represents a very marked difference in attitude on the part of the War Department or by the Administration. This is a small departure from the point system on the part of the Army.

There are evidences that other re-

laxations of regulations with regard to releases from the services and with regard to Selective Service will appear from time to time. One can look forward perhaps before very long to an action on the part of the Navy similar to the Army action. However, full agreement has not yet been reached.

CHAIRMAN HOLLISTER: No doubt you have questions you would like to ask Dr. Trytten about some phase of Selective Service, and I am sure insofar as he can, he will be glad to answer them.

DEAN LIND: May I ask, in regard to this last category of man that you referred to, must be devote 100 per cent of his time to research or could he be used as a teaching assistant part-time?

DR. TRYTTEN: Are you referring to the Selective Service or the Army situation.

DEAN LIND: I am trying to get a man out of the Army that had a bachelor's degree.

DR. TRYTTEN: I am not sure about that, because all I know is the language I have read to you. But I would say that it is very likely that any combination would be satisfactory. I think the reason would be that an institution that wanted a man would certainly be in a position to ask for him as a teacher, and after a time change his duties. If you see what I mean? I am sure the Army would recognize that possibility and would be realistic. Furthermore, in the case of Selective Service, which represents a changed administrative point of view, the individual can be deferred for any combination of teaching and research, or all teaching or all research, and I am sure the same philosophy will extend to this Army situation.

DEAN CLOKE: I would like to ask what would be the procedure in trying to get a man out that you need?

DR. TRYTTEN: I would ask for him individually; that is, write to him individually and ask him to apply for this release under the new policy. That is Paragraph—if you want to take the numbers down I can give them to you again. This is Paragraph 3 of Regulation No. 615–365, a War Department regulation. I am not certain about the date, about the fifth of December.

QUESTION: That applies only to men in research, is that correct?

DR. TRYTTEN: No, it applies to men who have been accepted for graduate study for teaching or for research.

SAME QUESTIONER: No, I mean their activity in the Army. It doesn't apply to everybody in the Army?

DR. TRYTTEN: No, and that was a disappointment to us. We had hoped it would be wider than that. And I might say it appeared to be to the Administration originally but modifications appear to have been made.

SAME QUESTIONER: And is it comparable in the Navy?

DR. TRYTTEN: I am hoping the Navy will come out very soon with similar regulations. The Navy has been considering a similar directive, but the services are reluctant to jeopardize the point system and the Navy has so far not finally agreed to a specific release. The people we really want to get out more than any others are not the people who are now doing research work in the Army, it is the people who are not doing technical work but are nevertheless qualified. They are desired, and it is hoped the services will later include them.

QUESTION: Would this include all men engaged in research now being put under 1-A by their Selective Service Boards?

DR. TRYTTEN: Yes, that will be covered. A request should be made immediately to reconsider their case in the light of this release.

W. N. JONES: Would it be legitimate to pay the man who is out of the Army additional compensation, to that which he will receive from the GI Bill?

DR. TRYTTEN: Well, I am not too sure about that, but I think the decision there depends rather on a matter of time. That is, if he is doing full time work, then he would be getting full time pay. I am not too sure, I don't think I want to go on record there.

COMMENT: It answers his question.

W. E. WICKENDEN: I wonder if you would be prepared and willing to comment in any way on the outlook for extension of Selective Service legislation?

DR. TRYTTEN: You mean beyond the present time, May 15? Well, I think it is too early to say, because it will depend on a number of things. It is going to depend on congressional action on universal military training to some extent, and I think it is going to depend to a very large extent on what happens in China and in Germany. I might say that it has been my own hunch that we are going to be forced to make some fundamental decisions before very long in the United States with regard to foreign policy. As a matter of fact, we have already been forced in China. It seems certainly likely that if we take a positive position in China—and I don't see how we can take anything else—then we are going to be committed to a fairly large army over there to implement that policy.

The same thing I think is going to take place in Germany. We may withdraw completely, but I don't think we are going to.

Now if we have to have armies of the size of several hundred thousand in these places and these armies will need manpower back of them in the United States, that begins to add up to a total that makes it very questionable whether we can get them in by voluntary enlistment. That question has to be decided first, you see, whether we can get them by voluntary enlistment. The figures seem very encouraging now. I think the figures for November are around 81,000 enlistments in the Army. There was, however, some kind of a deadline in November that influenced enlistments so I don't think it is typical. I don't think the answer on enlistment will be available until late in the winter.

By the end of February we ought to know pretty well how enlistment is going to go. If you want my guess, I am personally of the opinion that Selective Service will go beyond May 15. That is the way it appears to me right now. But I wouldn't bet very much on it, because I think many things might change it.

E. B. NORRIS: Is there any way of staying the induction of a senior who has been up until now classified in 4-F and then suddenly changed to 1-A and ordered up for induction, within perhaps only three or four months of getting his degree?

DR. TRYTTEN: So far as I know there isn't, I don't know of any.

COMMENT: Except to trust to the judgment of the local board. In many instances the local board will do it.

DR. TRYTTEN: Yes, that of course has applied all the way through, too. I think in a case like that it might be well to call attention of the local board to the change in attitude throughout

the Administration. They are sensible people, in the large majority of cases, and as you say, I think they might be likely to go along in a good case.

QUESTION: Has there been any plan of increasing the number of volunteers by considerably more pay to the soldiers, and thereby avoiding Selective Service, even though you have to maintain a larger Army?

DR. TRYTTEN: I think so; I think we will probably go quite far in that direction. I don't know of any concrete proposals. I think, of course, the Army has gone as far as they can under present directive. Congress probably would have to decide how much farther they can go. And I know a number of the members of the Military Affairs Committee are thinking along that line. But I don't know anything definite right now.

Condensation of a Report on Course XV, M.I.T.*

By ROBERT W. KING
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Introduction

The study asked for by the Visiting Committee of Course XV, Business and Engineering Administration, of Massachusetts Institute of Technology is one which could not be undertaken lightly.

Engineers among the professions have always been outstandingly prone to inquire into the mysteries of the educational machine, to propose measurements of its efficiency and to test the quality of its output in accordance with various standards of measurement. As a profession they have, for fifty years, maintained a Society for the Promotion of Engineering Education; and this Society, by the record, appears to have been actively inquisitive and duly prolific of suggestions. It has held frequent meetings which have been well attended by both practicing engineers and the academic fraternity; it has published a monthly journal devoted to problems of technical education; it has financed ambitious surveys of opinion and experience; and on its various committees many of the best minds of the profession have served over the years.

And this but represents a sort of normal level of activity. Within the last decade, discussion of engineering education has become more intense; committee resolutions more importunate; and by no means least, other groups, notably political and labor, have begun to manifest a willingness to step in and dictate what the conduct of the profession in many instances ought to be. It becomes increasingly evident that the future leaders among engineers must be more attuned to the full economic and political repercussions of technology, and trained to accept greater social trusts than were their predecessors. Otherwise the penalty threatens to bind the profession within a growing framework of legal interdictions, reared with but accidental regard to whatever conditions will enable technology to render its greatest service to society.

It is in these turbulent waters of inquiry that the present writer undertakes to execute a few demonstration strokes. It may naturally be wondered whether any effort of his can possibly prove significant. There is likewise small chance that any willing rescuers will be on hand should the current prove too much for the hapless swimmer. If this is not an assignment which the proverbial angels would shun, it certainly is one in which nothing smaller than a celestial platoon would venture, and then only with reenforcements handy.

A single extenuating consideration is to be seen. Few men with extensive

* A Report to the Visiting Committee of the Course on Business and Engineering Administration (Course XV) of Massachusetts Institute of Technology, of October, 1944.

business or practical engineering experience have found or taken time to reflect at length on the subject of engineering education, or even on the more restricted theme—which is our present *corpus delicti*—of training for administrative duties as an adjunct to such education. Perhaps something will be gained by attempting to fill this gap. In so far as the experiences of a practical man confirm the views of the academician, the facts will thereby become that much clearer; in so far as they disagree, then within the area of disagreement it may be that neither has yet grasped the truth.

The present discussion and recommendations are necessarily quite general (they are not directed toward the coming period of demobilization, but to the more distant future) and, as they stand, bear little more relation to Massachusetts Institute of Technology than to other schools giving a university level of scientific and engineering training.

American engineering schools and colleges took official cognizance of managerial problems about a generation ago. Recognition of a trend which has since become more pronounced led to the incorporation of various business courses in the engineering curricula. In fact, so numerous have the instances become in which men trained in technology have had responsibilities of management thrust upon them that it is surprising to find the present-day enrollment in this (we might say, hyphenated) course in business administration to be but a minor fraction of the general engineering enrollment. This suggests that there is still considerable doubt in the minds of all concerned as to whether the hyphenated course, when limited to four years, can—save for exceptional students—impart either the technical or administrative training upon which to build a successful career.

I shall not, at this stage, speculate as to whether this is true, nor whether such courses deserve greater popularity among undergraduates. It might be mentioned in passing, however, that past and current evidence suggests that students completing these courses have had no difficulty in finding employment. The not very extensive records at hand also suggest that engineering-business graduates have about the same expectation of promotions and salary increases as do engineering graduates generally. None the less, there is reason to believe that a goodly fraction of those enrolling have done so because they expect upon graduation to enter some relatively small business, perhaps a family undertaking, where one can quickly apply the limited introduction to business methods provided by such courses.

It would manifestly be unfair to undertake a detailed discussion of the hyphenated curriculum without some initial review of the broader field of engineering education to which it bears close kinship. But more broadly than this, since the curriculum in its present form has been designed to prepare for careers in industry as operated today, and such changes as are made in it will presumably spring from the hope of providing better preparation for the duties and responsibilities of the future, let us first cast a look ahead.

Setting of the Inquiry

Every generation is inclined to look upon its epoch as a turning point in history. Every generation has made discoveries, has committed errors, has reached conclusions, has deliberated upon facets of experience which never

before have confronted mankind. All such acts are irreversible, and by observers close to them in time are likely to be regarded as constituting in their entirety a sort of fulcrum about which the tide of human affairs, for better or for worse, is being swung into new channels.

From this standpoint the present generation has considerably more than an average assortment of new elements to ponder. And implicit, if not explicit, in most of them is the handiwork of the engineer. Within thirty years we have been the victims of two world wars and a prolonged economic depression. Technology is the body, if not the soul, of these outstandingly antisocial phenomena. Yet the engineer has clearly not willed that his skills be thus used to debase the course of events. Paraphrasing Emerson, he has not even consciously been a passive master lending his hand to some vast soul that o'er him planned. Yet he has been an important accessory before the fact. Moreover, as is axiomatic, his technology will have an increasing influence in molding life and creating new and serious social problems in the future.

What preparation, then, will be most appropriate to tomorrow's careers, especially those in technology and management? For answer, we must examine the major social, political and economic trends, noting their past courses and gauging their future, remembering the while that in such movements there are few discontinuities, few sudden beginnings and abrupt terminations, but frequent changes in rate of motion and of emphasis. In most respects, social, economic and political problems arise more from accelerated rates of change and sudden shifting of emphasis than from altered directions; slow changes present but minor hurdles.

The Western world has come a long way since Newton remarked that he was but a boy upon the seashore who now and then happened to find a rounder pebble or a prettier shell. It is not that the extent of the shoreline has grown perceptibly greater since Newton's time. He was as clearly aware of its infinite extent as we are, but, whereas he claimed merely to be seeking an occasional bright pebble or a fascinating shell, we have discovered gold; and a rush, far transcending that of the Forty-niners, has blackened the sands with beachcombers as far as eye can reach.

Knowledge, at least knowledge of the physical world, has become transmutable into wealth on a scale that far outreaches the dreams of earlier ages. Although knowledge for its own sake is as yet neither a forgotten ideal nor a neglected pursuit, a dominating urge now springs from the hope of practical applications, cash returns, and an easier way of life.

This has given rise to what is probably the most urgent problem before the industrialized nations. Their task is to effect a continuing integration of the expanding industrial system into their existing and essentially liberal social and political forms. It is a problem which assumes greater proportions the more liberal the political forms and framework into which the fitting is to be done. This, in turn, is but another way of saying that, while liberal governments (by definition) permit extended individual initiative and freedom of action, experience is demonstrating more and more clearly that such privileges can remain unconstrained by some sort of controlling authority only in proportion as they are

based upon an increasingly high order of individual wisdom and judgment.

Nowhere do we find better illustrated the ambivalent character of human affairs than in the system of checks and balances which must come to guide and govern the domestic and international operations of a smoothly running industrial nation dedicated to free enterprise. We usually associate checks and balances with political institutions but they are an equally needed part of our economic machinery. Each of the processes upon which the trade life of a nation depends injects its peculiar menace when employed to excess or allowed to run beyond quite narrow bounds. Money is essential to easy trade, but too much money—an inflated currency—introduces risks and hardship. Credit is a promoter of trade, but over-extended credit is likely to lead to disaster. The continued development of labor-saving machinery is essential to progress, but technological unemployment may turn the balance unfavorably. Saving is essential to the creation of capital goods, whence progress takes its rise, but excessive saving jeopardizes the market which the capital goods were created to supply. The growth of cities has created large labor markets and stimulated industry, but their crowded denizens, denied the stabilizing influence of the ownership of property, are a political factor of unpredictable import.

So the list might be extended almost indefinitely! While competitive enterprise has many virtues, more and more must it be dispassionately guided if adjustments essential to the smooth functioning of the liberal economic system are not to be upset. The causes of trade cycles, of booms and depressions, of the growth and contraction of credit, of the aging of industries as new lines of endeavor arise and make inroads upon them, are all much easier to comprehend than is a mechanism—whether it be chiefly legal or chiefly of spontaneous operation—which will constantly adjust their causes to one another and preserve within an industrial nation a felicitously steady state, or an equally felicitous steady rate of growth. The experience of a century and a half has shown that, unless trade and employment are not to be seriously upset at least once every generation, such a nation must be competent and prepared to advance by carefully calculated and measured steps that are more suggestive of reasoned, statesmanlike agreements than of free competition.

And as for the United States in this respect, if we cannot initiate promising non-political controls soon, the grasp of the federal government is likely to have become so firm as to make free enterprise but a memory—a memory to be more and more cherished, the farther it recedes from us.

No trend with which the liberally minded peoples of the world will have to reckon is more significant than this rise of statism. Yet the tide of bureaucratic control, encroaching upon individual liberty and free choice of action, is an old phenomenon even in the liberal governments of the Western nations. The situation which alarms today was clearly foreseen seventy years ago by Herbert Spencer in his "Coming Slavery." He warned of the loss of individual freedom, the mounting costs of bureaucratic regulation and control, the rising tendency of the State to tax, to levy and to expropriate. But old though the trend is, one suspects that our children, and their children in turn, will find small comfort therein. Its acceleration in recent decades gives every evidence of being essentially ir-

reversible, our protestations notwithstanding that ours is a constitutional republican government.

The various ways in which the industrialization of the Western nations has speeded their trend toward statism are too well recognized to need review. And to the already long list we may expect that yet others will be added; one of these just now looming over the horizon may appropriately be mentioned in passing because it is completely technological in character. We can now clearly foresee the time when a greater number of the Western peoples than ever before will have had their ties with the past suddenly and irrevocably broken. In the vast but relatively undeveloped countries, China and Russia, the war will, moreover, hasten the espousal of modern industrial methods at the same time that it obscures a popular understanding of the slow steps by which, in the Western countries, these have evolved—steps that were unavoidably slow because of the lack of underlying scientific knowledge. I think one can predict, therefore, that an effective majority in most of the important nations will adopt an attitude somewhat antipathetic to extensive private ownership and operation of essential industries.

How natural such a state of mind can be in the postwar world can perhaps be better pictured by supposing that with the coming of peace we in the United States should find ourselves either without railroads or with very inadequate rail facilities, yet possessing full knowledge of railroad equipment and techniques. Or again, that the art of electrical communication were spread before us, but not the instrumentalities; or that various other basic industries were available in thought but not in fact. We can readily appreciate that no so-called venture capital would be needed to launch them. With an already existing demand, the problem would not be one of stimulating market development, but of finding capital and manufacturing facilities rapidly enough to satisfy the pressure of public demand.

The countries of the postwar world that are without adequate backbone industries will be in much this situation. To them it will seem quite natural that government undertake to supply basic needs, especially as to heavy industries and utilities, as an item of public policy. With most of the world in the throes of this transformation, serious repercussions in the United States can scarcely be avoided. Were it only because of the interchange of ideas this would be true enough; but competition in world markets between State-owned businesses and those privately owned is likely to create situations in which the latter will increasingly seek assistance in and through government department and will yield to bureaucratic pressure.

These remarks but point up the increased attention which must be directed toward the *delayed,* and hence ineluctable consequences of technology. The now common technique of waiting for an ill or a maladjustment to assert itself, then tinkering with it with little or no regard to indirect effects is a form of social and political extemporization less and less to be tolerated. Such operation of the modern nation may be likened to driving a huge ship at high speed without a helmsman. Many of the most refractory problems in industry and society today have been born from seed unwittingly sown one, two and three generations ago. Too frequently have leaders in both government and indus-

try played the opportunist role. And while ignorance may once have furnished an excuse it scarcely comforts those upon whom the delayed penalties fall.

Such in brief appears to be the stormier political weather into which we find ourselves careening, and with it the coming generation is likely to be more concerned even than we. Not the remotest corner of education will completely escape its gusts and squalls. And as for technological training, it is almost certain to be struck by the full force of the mounting wind. Likewise training for management and for public administration threatens to draw the lightning and feel the strongest blasts.

Both of these fields of education intimately touch the border-line area with which the present analysis is concerned, but prior to readying our ship and securing its cargo in anticipation of the blow, let us further broaden our perspective by reviewing certain other long-term trends out of which significant future events are likely to be born.

Training Versus Education

Specialized curricula in institutions of higher learning we now take for granted. Medicine, law, divinity, science and engineering, and more recently domestic science, business administration, journalism, music, even dramatics and hotel operating, feature the catalogs of American universities. More or less in the order given, they have been canonized and accepted for inclusion in the utilitarian scriptures. Seen in retrospect, their rise and differentiation mark a slow and seemingly natural evolutionary development. But by even the casual observer it must be admitted that imperceptibly the aim of the academic world has shifted more and more from education and culture to applications and specialized training. Academic officialdom now puts its stamp of approval upon a livelihood rather than a balanced life; in consequence, it puts the material productivity of the individual to the social group above his importance to himself. It gives the highest academic sanction to the studies which rate as economic capital rather than to those which fructify in culture.

Incidentally, we again observe a swing toward statism—not by blatant assertion, of course, but by implication that the individual's highest mission is a utilitarian one toward society.

Current discussions concerning the educational world—and not alone the American sector—suggest the imminence of a reactionary tide. The real burdens of the recent war have been borne by the youth of the world. Moreover, it is the youth who in large measure must contend in the future with the jumble of unpremeditated legacies we and our forebears have let pile up. President Lowell long ago pointed out that youths, when they go to college, carry something with them which they in part leave behind upon graduating. Perhaps this was never so true as of those who will shortly be entering college. They are well-stocked with questions of a sort that even the wisest faculty cannot answer; yet in proportion as a faculty are wise will they regard such student gropings as a stimulus to further inquiry.

But it is not alone among students that one encounters misgiving and solicitous inquiry. Questions like the following arise on every hand. How can the college student—and youth in general—be more firmly indoctrinated with respect to his place in and his humanistic obligations toward society?

Is he being made sufficiently aware of the evolutionary record of human progress so that he can, in his turn, assist in plotting a rational future course for the nation of which he is a member? Now that man has taken into his own hands the custodianship of more and more effective instruments of destruction, how can his faculty of moral judgment be sufficiently developed in youth to insure his controlling enormous power wisely?

Such questions reflect the perturbation of mind in which many are seeking to examine present-day educational aims and procedures, particularly at their higher levels, and the doubts upon which they hope for reassurance.

Yet, as we envisage more clearly the world's enigmas, the less adequate do the processes and promises of education seem. To borrow a figure, our present position from certain points of view is scarcely more favorable than that of the polar bear afloat on a cake of ice in the Gulf Stream. Yet none among us can reconcile himself to a fatalistic view. Considering the great success attending exploration of the physical world, we are loath to admit impotence in the field of social phenomena no matter how tough the going. With a ringing challenge, the words of the poet reassert that "the proper study of mankind is man."

And accepting this challenge let us, as a first step, attempt some sort of measure of curriculum efficiency; *i.e.*, let us visualize as best we can what might reasonably be expected were we to undertake various shufflings of the components of present-day college courses.

The Promise in Curricular Revision

In the long annals of education, the technological curricula and the business courses based upon them are relatively newcomers. This does not deny us an adequate baseline, however, with which to gauge their effectiveness.

During the past century and a half the physical sciences, and their practical applications as well, have proliferated and fructified with amazing rapidity in all departments. By 1850 rudimentary dynamo-electric machinery had appeared. The land telegraph had already focussed attention on one of the important practical uses of electricity. The submarine cable was a proven success by 1860. By then, the foundations of organic chemistry had been laid, with the discovery of oil a few years later presaging important industrial developments. The invention of the internal combustion engine followed upon the heels of the development of the mechanical theory of heat and the principles of thermodynamics. Then, too, came Maxwell's electromagnetic theory, paving the way for Hertz' discovery of electric waves. And shortly thereafter invention became prolific with the telephone, the arc lamp, the incandescent lamp, fairly efficient means of converting mechanical to electrical power, and then electrical traction.

Such were but the major pillars in a structure of almost infinite detail. The incentive to establish engineering courses sprang naturally enough from these practical and lucrative applications of a rapidly expanding quantitative knowledge respecting the physical world.

The sequence of events in the educational world did not move at equal pace in all countries however. Save for instruction in higher mathematics, which had come to be considered a legitimate accessory to the classical education, England lagged behind France and

Germany, and also behind the United States, first in scientific instruction, and then in instruction in engineering. Such conservatism on the part of the English schools is the more remarkable in that England produced many of the individual giants of physical science during this period of its exuberant youth, of whom Faraday, Maxwell, Kelvin and Rayleigh are illustrative, as well as others too numerous to mention who were pioneers in engineering. This conservatism in England seems stranger still when we recall that the industrial revolution came to fruition first in England, making of it for a century or so "the workshop of the world."

In the United States, in spite of the fact that most of our culture has its roots in British tradition, engineering education found its protoype in Germany and France.

The nineteenth century educational differences between conservative England and liberal Germany are set forth by the following from Professor Huxley, written about seventy years ago. He says, "The German universities, from being beneath notice a century ago, have become what they are now—the most intensely cultivated and the most productive intellectual corporations the world has ever seen.

"The student who repairs to them sees in the list of classes and of professors a fair picture of the world of knowledge.—Every Bursch marches with a professor's gown in his knapsack. Let him become a great scholar, or a man of science, and ministers will compete for his services."

And again, contrasting England with Germany, he declared, "If a student of my own subject shows power and originality, I dare not advise him to adopt a scientific career; for, supposing he is able to maintain himself until he has attained distinction, I cannot give him the assurance that any amount of proficiency in the Biological Sciences will be convertible into, even the most modest, bread and cheese. And I believe the case is as bad, or perhaps worse, with other branches of science. In this respect Britain, whose immense wealth and prosperity hang upon the thread of Applied Science, is far behind France, and infinitely behind Germany."

Now, let us look for a moment at the difference in national performance which may reasonably be attributed to this difference in training. We recall the amazing speed with which Germany advanced as a manufacturing and commercial nation between 1870 and 1914. To cite but a single illustration, it was during this period that she outdistanced all competitors in the field of organic chemistry, and entered the first World War much the gainer thereby. In the United States a similar, though perhaps less spectacular, development took place. Under the impetus of a growing army of competent technologists aided by adequate stores of raw materials, industrial applications of science swept forward. From its pinnacle, England dropped to a position in which (save for Empire preferences) she was rapidly losing ground to German and American competition.

The practical achievement that can be credited to the scientific and engineering schools on the basis of this comparison is clearcut and unequivocal. The record is among the most impressive to which pedagogy can lay claim. Hundreds of thousands of individuals, largely self-selected on the basis of some more or less definite urge, and subsequently drilled in the facts of science and engineering, have worked

their way in and upon the Western nations, with the results that speak emphatically for themselves.*

This observation is but preparatory however to noting a more fundamental basis of this success.

The pedagogic content of technology involves factual knowledge—not unrelated nor unassociated—but largely bound up in definite relationships. It makes but a minor demand upon the faculties of judgment and intuition. Rules of procedure and practice, based upon these relationships, tend also to have a marked quantitative aspect which permits the majority of technological graduates to spend their adult lives in systematic application of such of these principles and modes of procedure as have become familiar to them.

Thus, from facts to principles, to practices, we find a logical series of stepping stones. Lastly, the pragmatic test of quick commercial success or failure has been at hand to stimulate application and to evaluate the final stage of practice. The continuity, though more varied and involved, is in many respects as definite and tangible as the continuity of Euclid. The teachers of technology have been notably successful in inculcating just what Henry Adams said education should inculcate, viz., the ability to react with vigor and economy; but the gamut of reactions has been conspicuously circumscribed.

Now if we could assume that the future supplements to the engineering curricula are to be of like character, presumably like results could be anticipated. But the earlier section entitled "Setting of the Inquiry" has, I trust, prepared us to reject any such assumption. The essential diffuseness of the new material threatens to disturb the Euclidean appearance of the scene. There are no immutable Kirchhof's laws defining the flow of goods and money through the channels of trade and no Newton's laws of motion which social forces and the mass-man obey with precision. Accepting, then, the view that many of the important tasks to be laid upon the coming generations of engineering graduates will involve questions of broad social character, we find it difficult, good utilitarians that we are, to escape the conviction that the part of their college training which prepares for these social questions should match the efficiency of the part which bears technological instruction.

Hence, in procuring additional curricular material, we shall have two conditions in mind, one pertaining to its factual adequacy, the other to its pedagogic form so as to approximate as well as may be the formalized characteristics so much to be desired. There is no need to apologize for the difficulty of meeting these requirements, though they do seem to demand little less than the quintessence of all knowledge. I hazard only one suggestion, and do so with all possible humility and no claim to originality.

Broadly speaking, the study of the social and political panorama can be pursued by two different methods. One is intensive, in which more and more facts concerning a particular period or brief era brought to light and discussed. The other is extensive and, paying only necessary attention to detail, attempts to discover or portray long-term trends and cycles. The intensive methods must necessarily sac-

* Of course, engineering did not supply the first illustration of advanced educational drill in the use of factual material. Medicine, law and divinity all preceded it, but perhaps not even medicine has permitted as convincing a test of pedagogic efficiency.

rifice perspective for exhaustiveness and of course has its uses; the extensive method takes a far-reaching and sequential look into the past and when adequately developed, should be more helpful as a basis for forecasting the future significance of present-day events and policies.

To pave the way for this proposal, I have already cited trends which loom significantly today. In a sense these play a role analogous to the statements of general principle which characterize the more exact sciences. In so far as they do this by epitomizing cause and effect, they should serve well as instructional guides. Due, however, to the involved and shifting nature of much of the subject matter of the social sciences, we must make due allowance for basic conceptual differences between them and the relatively exact sciences. For instance, the test of truth in the physical sciences is usually regarded as the ability to make accurate predictions (the submicroscopic domain where the uncertainty principle enters significantly being an exception), whereas in the field of social phenomena it is apparent that the mere act of making or publishing a prediction will sometimes reduce or remove the possibility of that prediction coming true. This is not the place to engage in epistomological discussion, but it is worthy of note, though not equally worthy of commendation, that there is an increasing tendency displayed by physical scientists to ostracize social studies from a worthy place in the roster of the sciences on the basis of their rather qualitative nature.

As related somewhat to this discussion of the importance of trends, I wish to mention a recommendation recently placed before the Society for the Promotion of Engineering Education. The sponsoring Committee hopes to see the engineering student of the future led systematically through the elements of history, sociology and government. Its suggestion to educators is, "Formulate the results sought as explicitly as possible; select appropriate materials with discrimination; and arrange them in unified, developing sequence extending through the curriculum."* Again, "Attitudes, emotions, feelings and beliefs are among the primary forces motivating conduct and behavior. These are obviously the fruit of nurture and indoctrination, but may be brought to effective maturity as they are refined by critical thought, by experience, and by faith. The role of the college in these processes of nurture and refinement, while not easily defined, is none the less real and insistent."

As they bring this recommendation forward one sees the Committee in anxious indecision concerning the horns of its dilemma. Thoroughly familiar as its members are with the carefully formalized courses of the engineering curricula, and well acquainted as they are with the type of student mind which appreciates order and logical definiteness—because for the most part this type elects engineering—it yet feels impelled to advocate the inclusion in engineering curricula of a rather extensive selection from the social-humanistic category. Perhaps to mitigate somewhat the discomfort of their position, they suggest selecting "appropriate materials" from the social-humanistic domain that are characterized by a "unified, developing sequence." And to secure this the Com-

* Report of Committee on Engineering Education After the War. JOURNAL OF ENGINEERING EDUCATION, Vol. 34, page 589, 1944.

mittee emphasizes that the new addition should be carefully planned, not leaving each part to the individual discretion of its teacher, nor even department.

To some critics, such added emphasis upon the social-humanistic areas will be looked upon as a dilution and, in a sense, a lowering of standards. But critics, like others, sometimes change their opinions in response to changing circumstances. An interesting contrast to our present situation lies in the Wickenden survey of eighteen years ago. In that survey, of respondents in administrative and commercial positions, 60 per cent rated college training in economics as of great importance; but of those in technical positions, less than 35 per cent considered it of great importance. It is also interesting to contrast the present swing toward social and humanities studies with opinion expressed then. In order to make room in the engineering curriculum for more economics, 45 per cent of respondents favored reducing the already small cultural content; 35 per cent favored reducing the technical content (chiefly shopwork); 13 per cent suggested reducing the scientific content; while 7 per cent would have reduced the hours given to the study of English.

There are also those who believe, or did believe, that courses in administration and management have added a bit of intellectual laxness to the rigid discipline of formal engineering. I would plead, however, that such notions may be based upon a misconception. To illustrate, let us ask ourselves which engineering problem is likely to be easier: that which is quantitative throughout and when solved comes out with a definite numerical answer, or the problem which involves human responses and perhaps operating conditions that are difficult to define explicitly, and therefore presents a substantial number of possibilities or contingencies, permitting of various answers, each one based upon a special appraisal of the initial conditions. I think there is little doubt but that to the student mind, and usually to the adult mind as well, the definite problem (provided it can be handled at all) is simpler and more acceptable. So as engineering curricula broaden and draw in instructional material from the less codified realms of knowledge, their formative and guiding influence may weaken while they actually become more difficult to the rank-and-file of engineering students.

Another debatable opinion affecting the value of social-humanistic supplements springs from the observation that supervisory positions in technological industry must be filled by men of scientific or engineering competence, and that many of these incumbents in time will advance to occupy positions of high executive and advisory importance. This sequence of events has occurred so frequently in recent decades as to have suggested to many what I suspect is a *non sequitur,* namely, that because engineers are now found in important managerial positions, it is permissible to conclude that their engineering training in college has been well adapted to serve as a foundation for discharging the responsibilities of those positions. The opinion is in part valid and in part misleading. No one can dispute that technological competence must be well represented in the higher levels of the management of technological businesses. But there is clearly no evidence to support the view that a technological training forms the best basis for undertaking management

duties, nor is there any support for the view that technological training may not be improved if supplemented by instructional material drawn from other areas.

If either of these latter views were correct, there would, for one thing, be little point in such a study as the Visiting Committee is now undertaking. But what is more to be remarked, where would we then look to find amelioratives to the social and economic enigmas of the present day? Were the preparation now offered by the colleges as engineering and science courses definitely established to be the best possible for undertaking management's broad responsibilities, we might logically declare that technology had indeed rung the death knell of democracy.

Naturally, the defeatism of such a conclusion virtually defeats itself. By inference, at least, we reassert our faith in the educational process, admitting nevertheless that the writing of a better educational syllabus presents many a first-order problem. It is one thing to advocate the inclusion of more cultural material in the curriculum and quite another to satisfy ourselves concerning the efficacy of so doing. Such material has been the chief constituent of many college courses for many years—for more years in fact than the technological curricula have existed—and yet we find no particular record of practical accomplishment to point to. Upon consulting the record of the past, about all we receive is a warning not to expect very much. If, from the study (or teaching) of history, of morals and ethics, of sociology, of politics, of philosophy over the centuries, any truly significant values have emerged, they have influenced conduct to a remarkably small degree. Indeed, it might not do great violence to the facts to assert that, on the whole, the early Greeks had a more adequate comprehension of their world than we have of ours. Of course, theirs was simpler, but this does not gainsay that in practical workaday political knowledge we have lost ground in the space of two thousand years; that in the words of the White Queen, for all our running, we have not quite been able to stay where we were.

The sum and substance of this dilemma might be stated as a lack of sufficient factual data together with inadequate analysis and codification of the data now available. It is difficult to see how undergraduate curricula can be significantly improved until further basic research and exploration have been carried out. We must find readier means to cut through the confusing screen of daily events to the slow-moving, long enduring, but significant currents below.

Faced with this acute need, the greatest honor we can confer upon our institutions of higher learning is to urge them to explore this difficult subject matter, and, while pushing back the frontiers of ignorance, expand their curricula so that each fresh class of graduates will have had the exciting privilege and stimulus which comes from realizing that one has walked in the company of an explorer. There is a vital mission here fore the advanced schools of technology as well as for the institutions traditionally concerned with the social-humanistic areas of learning. In fact, not only the former's mounting responsibilities but the increasing need of effective liaison coupling investigators and scholars in these now separated areas, summon them to launch programs of research and graduate instruction in the social and politi-

cal domains second only to their present efforts in behalf of the physical sciences and their applications.

Aptitude Identification and Student Selecton

In the main, the facilities of higher education have always been distributed or allocated by a process of spontaneous selection. Students who have applied for courses in higher mathematics have for the most part been in possession of a natural aptitude for such endeavor,—similarly in the sciences, the classics, medicine, music and law. But in the domain of business administration such spontaneous selection cannot so clearly be relied upon. It is certain that not all the students who elect business and administrative training possess native endowments which will enable them to go far in managerial duties, though current experience does show that a not insignificant fraction have the requisite ability. For the most part, business now provides its own processes of selection, and it seems reasonable to assume that on the whole these are operating satisfactorily and are not likely soon to be replaced. In fact, it is difficult to see how any selection earlier than the pragmatic filtering performed by business could be very successful.

Least likely of all is it that the business schools could confidently separate incipient management talent from the main stream of student material. Latent talent in management is usually slow to appear. Even advanced schooling would largely be over before its existence or lack could be reasonably established.

Moreover, one is tempted to remark that competent selection within academic walls is, if anything, made more problematical by the general willingness of educators to underestimate the differences which Nature has introduced among their students and to magnify the importance of this or that pedagogic method and this or that course or curriculum. Frankness in such matters is a rare but shining virtue. Cynical smiles do not often enough greet the faculty conclaves, the papers, and even books, that aim to set up the *summum bonum* of curricula, or of methods of instruction, as though the usual student group consisted of units virtually identical to one another. Educators not infrequently discuss their techniques with the meticulousness of engineers planning a production process, but the fact that the youthful material entrusted to them has stood its ground so consistently under all sorts of educational schemes and in all times and places, suggests that Nature has had a considerable hand in controlling the outcome, and that for reasons of her own she has willed it that scholars shall be about as scarce as champions of the prize ring.

Mystified though one may be by the persistence of the teaching profession to underrate inheritance, he must not fail to see its members for the idealists they are. Nothing so clearly evidences the humility of the true craftsman as to find little or no fault with his raw materials. In this regard teachers by and large are exemplary, tacitly maintaining that if the end product of their pedagogic processes fails to measure up to expectations, the blame rests chiefly upon the processes and those who operate them, not with the inherited aptitudes and limitations of the raw material.

There are limits, however, beyond which the educator cannot in wisdom go in overlooking natural endowment, and particularly is this true of courses

in business administration and management. Deliberate and explicit undergraduate training for management can turn the heads of novitiates and the subsequent disappointment may be peculiarly poignant. This is a matter which deserves emphasis in spite of the fact that business schools are by no means unaware of the danger and for the most part are attempting to operate filtering processes of one form or another.

It is not necessary here to emphasize the vast amount of rather quantitative data, extending from Francis Galton to the results of current placement tests, that are now available respecting the range of human faculties, all of which confirm the point of view just expressed.

Let us turn, therefore, to consider administrative ability from the standpoint of its component talents. While such ability probably extends over as wide a gamut as mathematical ability, or the primary talents in general, it appears rather definitely to be a complex of more nearly primary qualities.

Among the more important, or more commonly observed administrative talents or traits, the following certainly deserve mention.

A likable personality and disposition.
A pleasure in human companionship.
The instincts of a good housekeeper in the sense that one thinks intuitively in terms of orderly arrangements and procedures. A good executive is probably seldom disorderly in his thoughts and actions.
Courage, both physical and intellectual, associated with which is a relative freedom from worry.
Vitality, physical and mental, and an energetic and rapid worker.
A ready humor and repartee, a ready talker with charm or attractiveness of delivery and manner.
A good memory, especially for facts, experiences and faces.
Frequently, a proclivity to plan and vision for the future; in a sense, a dissatisfaction with the *status quo*.

To such equipment, knowledge and good judgment should preferably be added, but the pity is that there are, and presumably always will be, hosts of otherwise excellent leaders and executives whose judgments are quite unsound; as, conversely, there are many persons of sound judgment and broad understanding who wholly lack executive talent or interest in administrative duties.

To sum up, we might conclude that the good executive possesses to a degree well above the average a well balanced mentality; certainly, this conclusion harmonizes with the quite general fact that, by and large, good business leaders arise from among those who in their younger days were good students.

Such a listing at once suggests the difficulty of devising a test for high order administrative talent—at once simple and satisfactory—that can be applied to immature students, to say nothing of the identification of individuals who merely have more than an average endowment. It is one thing to test for an uncommon mathematical aptitude, or a propensity for science, art, literature, or music, and quite another to spot by a simple test the intellectual resources and talents of the potentially successful administrator.

It has doubtless occurred to the reader, while running over the talents listed above, that they lie more or less in the category of the cultivatable faculties, and from even small beginnings

something worth while can probably be developed by training and application. This is of prime importance, pedagogically speaking. Consider a single faculty such as memory; even a small native nucleus—while it could never be schooled into the proportions of a Macaulay—might after diligent training serve adequately the needs of many an excellent executive. It would be useless to speculate further here upon the possibilities inherent in such professional training (a kind of training now omitted from formal schooling and therefore ignored except as the individual may take himself in hand), but I put them forward as worthy of exploration by institutions of higher learning.

To explore a little further the fitting of job and man, there are many levels in the pyramid of management, and at each level a different class of skill and knowledge must be available if the organization as a whole is to function at its greatest efficiency. Speaking in general terms, the characteristic need of the lower levels is for detailed factual knowledge and the skill to plan and guide specific factory or office operations, engineering, accounting and other techniques, and the like. The group leader need have little knowledge of the work of other departments, and therefore little talent at coordinating or dove-tailing tasks of rather widely different types. Ascending the scale, the ability to coordinate, and to guide several distinct lines of work and have them deliver their respective end products on time and in proper relative amounts becomes necessary. And as the need for such supervisory talent becomes more prominent at each successive advance in level, the supervisor's views and considerations necessarily become more coarse-grained in regard to specific technical details. But with increased need for coordination it becomes increasingly important that the administrator possess the ability to judge men and to plan divisions of work into smoothly meshing parts. The call for leadership also mounts to a higher premium. Moreover, as the subject matter grows in generality with ascent in the pyramid, it becomes progressively less susceptible of quantitative statement. Ability at handling problems then rests in part upon broad experience and in part upon a gift bordering upon intuition, and not easy to define or evaluate, which that experience has seasoned.

And parenthetically, it might be observed that management's obligations do not stop here. This is but a view of them from the inside and as they control the functioning of the organization somewhat apart from its remoter environment. Management, as we have seen, has an increasing responsibility to society as a whole, which is being less and less adequately discharged in the handling of employee, market, and stockholder relationships. Management must see its job in the most inclusive terms, summoning enlarged social wisdom to its aid. As it now has a legal department to tell it what it *may* do, a research department to tell it what it *can* do, an engineering department to tell it *how best* to do it, and a sales department to tell it how to make a *profit* out of what it has done, it might well give thought to a sort of over-all evaluating department to tell it what it *ought* to do. The *ought* aspect is destined to play an increasingly important role in business affairs.

Viewing the metamorphosis of function and duty as we progress from the lower to the higher levels of management, we see in a general way where

knowledge and training acquired at school can fit in and be of assistance to its possessor. At the lower levels, scholastic education can provide much of the factual knowledge, and especially knowledge of technological processes and techniques, *i.e.*, knowledge of a specific, unequivocal sort. It can also provide instruction and elementary practice in leadership and in making decisions where the situation fails of full quantitative statement. But the gulf between these acts and those of top management in its domain of policy may, on occasion, be as great as that between freshman physics and a treatise on wave mechanics. Hence, in the climb up the ladder to higher rungs, the effectiveness of textbook and classroom learning tapers off, and something which probably only Nature can supply must take its place, this something being developed and guided by experience and study.

The situation is one which finds its parallel in the medical and legal fields. An ability needed before a practitioner of either profession can reach the summit in his profession is that of handling unusual and uncharted cases. Such talent suggests a strong intuition nourished out of a broad experience. Such rare individuals are able to take almost completely non-quantitative situations and come out with satisfactory, sometimes brilliant, solutions. Herein lies, in large part, the explanation of the great difference in earning capacity between even good engineers, exact in their thinking and in their methods of analyzing problems, and the top ranks of management, medicine and law.

Initial recognition has already been accorded the fact that the successful administrator must long remain a learner. It has given birth to the excellent arrangement of brief "refresher" (a patent misnomer) courses for those who are beginning to accumulate practical business experience. How important the word "brief" is cannot be stressed here. Such a limitation may not prove a particular hardship, however, since the mind, already conditioned by growing contact or association with certain practical situations, will in a few days acquire a surprising amount of cognate information, stimulus, and inspiration. As the universities increasingly search for and codify new knowledge, a natural setting for such continuing liaisons will spring up. And these, in turn, should develop until they become the instrument for attracting to campus conferences business men who have attained such industrial and intellectual stature as to warrant preservation of their ripened experience—those who have joined the sages and the seers, and in whom the cream of wisdom has had time to rise on the milk of experience.

A Working Partnership

The development of medical science suggests another standpoint from which to view the program that universities and business together can conduct in the field of managament. Even the ablest doctor or surgeon—*i.e.*, ablest by natural endowment—would be helpless without the vast reservoir of medical knowledge made available through the medical schools. The parallelism of management to this case is suggestive. Our stores of medical knowledge have been fed by two principal springs, the research of medical schools on the one hand, and the codified experience of the abler practitioners on the other, but with considerable overlap since many of the latter have also served on the faculties and as research experts at the schools. Hence, in a broad

sense, the experience and the knowledge of both sets of workers have merged to create present-day medical science.

Why not vision somewhat the same give-and-take being worked out in the departments of management, business administration and economics? Unlikely as it is that these departments of knowledge will ever be organized and coordinated to quite the extent that the science of medicine has been, they should expand under a partnership analogous to that which has stimulated the growth of the latter science.

As to which ways and means will prove most suitable, experience and circumstance may be expected to supply adequate guidance. Only one matter should perhaps be emphasized, viz., that representatives of management—like their medical counterpart—should be encouraged on every appropriate occasion to take a broadminded and liberal attitude toward the release of their experience and special knowledge for educational purposes.

But such liaisons between the academic and the practical worlds, to become fully profitable, must provide opportunities for faculty members to maintain first-hand contact with practical affairs. A consulting practice is the appropriate means to this end and the conditions under which such practices are carried on will vary greatly from man to man and from school to school.

Consulting practices will yield a knowledge of specific business and managerial problems to serve advantageously as "case" material for class discussion and the stimulation of student reading. In many of the courses dealing specifically with business questions and business techniques, the case method of instruction seems ideal. References to it are much more likely to be laudatory than not. Indeed, one eminent educator connected with a business school went so far as to declare that he could not imagine operating without it. And the respect in which the case method is held on some campuses suggests perhaps a word of warning; if it could actually accomplish all that its eulogists imply, it should follow that the faculty members who live with it and bask in its effulgence would, of necessity, become the wisest of administrators and so invaluable in the practical world that it is doubtful if universities could long hold them.

Projecting the possibilities inherent in consulting practices and in the development of the case method of instruction, one looks forward to many ways in which business will benefit from an expanding supply of *disinterested* knowledge and counsel. I have already mentioned the *ought* phase of business decisions and actions, but it will bear reiteration. It lies at the root of many of the problems which are general throughout the industrial world.

As an example, management today is elected or appointed by those whose capital is invested in the business. Here we meet a projection of the past. No matter with how full a measure of disinterestedness a management thus designed carries out its trusteeship, the suspicion of favoritism must attach to many of its acts. Yet in fairness to itself as well as the other parties at interest, it ought to be in a position to deal fairly with all—with labor, consumers and public, as well as with the owners. Various new complexions of management can be suggested, of course, which will afford direct expression of the interests of each group, and perhaps in

some kind of proportion to the magnitude of their respective interests. Whether progress lies along this line or in the direction of higher and disassociated management groups—perhaps attached to government bureaus—to compromise the conflicting interests of owners, labor, consumer and public is a question which deserves careful analysis and study.

Here is but an illustrative area in which it may be possible to carry out exploratory work by methods available to university research.

Many other areas of a general fundamental nature where academic effort could be expended with telling effect will come to mind and, in fact, are already treated as research fields by many institutions, though so far as I know by no technological schools. Legislation expresses the inability of the individual to guide his actions in accordance with the best interests of the group. As the social welfare of the nation becomes more and more closely interwoven with the conduct of business and industry, the temptation to safeguard that welfare will express itself in a multiplication of laws directed at the regulation of management. And if there are rules of conduct which all should obey, and which should operate without preference or partiality, the province of government is to define and enforce them. But it cannot be overemphasized that wise guidance of political action is vital to the continued success of a liberal state. Hence, the prosecution of broad investigations into such questions as hours of labor, the risks of technological unemployment, minimum rates of pay, geographical differentials, the philosophy and practices of social security, suggest close-working liaisons among the schools of higher learning, business institutions and government agencies; all prepared to give freely of their experience and opinions, while the schools, in so far as their research and exploratory programs are concerned, undertake to develop the facilities needed for analysis, correlation, and generalization. But the liaisons should never take such form as to jeopardize in the slightest degree full independence of academic thought and action.

Such topics typify the areas of study that are common to virtually all corporate business, large and small. They illustrate the abundance of vital topics for exploration by competent faculty members and groups, and which are now largely neglected by schools of technology. Only along this road can be found safe and sure antidotes to the political nostrums at which ignorance invariably clutches.

The approach provided by the popular ballot, as exercised at present, is almost antipodal to a deeply informed and judicial handling of such intricate problems. At the heart of much of today's anxiety lies the question as to whether representative government can be so *exalted* as to make it commensurate with tasks ahead. If improvements in representative government are found to accomplish this end, they will be political inventions of the highest order.

One such improvement can readily be pointed to, and all that lacks to bring it into existence are competent and trained men. There is little doubt that the directive and regulatory functions of central government are destined to grow both in number and in scope. Technology supplies a peculiarly rich soil for the culture of governmental bureaus. The evils commonly associated which such organizations arise mainly from the human limitations of their per-

sonnel. Even the iron-clad legislative rules under which they operate are an expression of these limitations. There is urgent need of persons in government employ who possess high native ability combined with broad scholastic training. In fact, since the basic supply of such individuals is all too limited, we may be approaching a point at which business will have to share with government. This could come about in part by the power and authority of bureau positions acting as a counter-attraction to the higher salary levels available in business. The program of research and advanced study herein discussed is therefore as vital because of the way in which it can leaven government as because of the direct aid it can bring to business.

Assuredly, it will be our national good fortune when we can look forward to a time of serious-minded cooperation to replace the open warfare now so common between business and governmental agencies. Not only is truth stranger than fiction but, on the whole, it is a great deal more complex, and therefore more difficult to understand. It is increasingly necessary to combat the insidious political value of high sounding phrases that promise security, equality, brotherhood, and liberty. All too rarely can socially attainable goals be set forth in unqualified terms. Integrity, sincerity and intelligence labor under mounting handicaps. The demagogue will always fool some of the people, and hopes for the future are based alone upon the spread of that kind of substantial information which will whittle away the margin of ignorance and emotionalism that he has available to work upon.

However slow it may be in yielding its secrets we are on the threshold of a tremendously important field of research—a borderline field that merges technology, sociology, political science and economics. As in most other fields of scientific research, many agencies must contribute to progress. Today, even many of the crucial facts of business experience are still unrecorded and hence uncoordinated. Too many of the approaches to new situations are empirical and haphazard. To the colleges we must look for men with the aptitude, the temperament and the leisure necessary to weave inductively the philosophical pattern that separates the significant and permanent from the ephemeral among the data of our industrial world, and illuminates them so that they become a beacon for wiser guidance in the future.

And though one knows that not for years will the picture become sharp and adequately revealing, let this not worry those who teach. Youth is the age of generalities and visions. Many a young man in college dreams dreams and conceives ideals which stay with him the rest of his life, and humanize, if they do not actually guide, the products of his maturer judgment.

Technical Education for Engineers in England

By W. ABBOTT

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The Two Main Divisions

The flow into the ranks of professional engineers in England is made up of two main streams comprising (*a*) the men who complete their education in a university and then acquire works experience; and (*b*) those who begin in industry at about the age of 16 and who acquire their education concurrently with works training. The number of those in (*b*) who secure a sufficiently high academic qualification to be regarded as potential professional engineers is somewhat greater than that of (*a*). Stream (*a*) is about 1,000 strong annually, stream (*b*) about 1,500, making 2,500 potential professional engineers per annum in all branches. This flow is regarded by many as being inadequate. A committee appointed by the last Minister of Education, Mr. R. A. Butler, under the chairmanship of Lord Eustace Percy, himself a past Minister of Education, surveyed the field of further technical education in 1945, and in their report recommended that the numbers of engineers should be increased, and that a third stream numbering about 350 should be produced via full-time educational courses of a technological rather than an academic character.

The Supply from the Universities

To consider first the university field. As is generally known, English universities are independent institutions governed in accordance with the provisions of Royal Charters or Acts of Parliament. Although the universities receive grants from the national exchequer, in varying amounts, and although the control of these grants is vested in a committee of the Treasury, nevertheless the universities retain their freedom in matters academic.

There are in England and Wales 23 universities, university colleges, or colleges providing full-time degree courses in Engineering. The length of a first degree course is normally three years and the period of attendance varies from 24 to 30 weeks per year. The numbers graduating in Engineering in all its branches were in 1939 between 700 and 800; to this number, however, has to be added those students graduating externally in technical colleges under the aegis of London University and totalling annually between 100 and 150; for, under the external arrangements of London University only, unique in the United Kingdom, approved colleges can prepare candidates for external degree examinations, and the courses of study may be full-time or part-time.

This pre-war total of something under 1,000 was more than maintained during the war by a State Bursary Scheme under which the flow to the universities in certain branches of science was stimulated by awards of tuition and maintenance allowances, under certain conditions. As a result the annual war-time output of gradu-

ates in Engineering was of the order of 1,250 a year, for the United Kingdom. The Percy Committee recommended that this war output should be maintained for at least a further ten years.

The curricula of the engineering courses at the various universities differ in detail, but they have much the same broad content. Undue specialisation is not encouraged, and although the divisions of civil, mechanical and electrical engineering are maintained in most universities, particularly in the third year, there is a strong body of opinion leaning towards as common a basic course as possible for all engineers. This is probably unattainable, but it does represent an ideal. There is also strong support for deferring the treatment of certain subjects, *e.g.* aeronautics, chemical engineering, fuel technology, to a post-graduate stage (*i.e.* what would be equivalent to a graduate school in the U. S. A.).

It is common practice for men upon completing their university course, particularly in Mechanical and Electrical Engineering, to enter industry for two years to acquire practical experience, at the end of which they may regard themselves as trained engineers qualified for a first and junior appointment. Not all graduates do this however; those who are research-minded may elect to take a higher degree with a view to entering a research organisation direct. It is not in doubt however, that works training is invaluable for all, whether it is taken prior to or after a degree course.

The Supply from the Technical Colleges

To consider secondly the other stream, made up of men who prefer to secure their practical and theoretical training concurrently. This is exclusively the field of the Technical Colleges. Many of these colleges are little inferior in status, if at all, to the provincial universities. Technical colleges in England are controlled by local authorities but are financed partly from the local rates and partly from the national exchequer. They are therefore the joint responsibility of the State and the local authority, in a kind of partnership.

In engineering, and particularly in mechanical and electrical engineering, a system of apprenticeship extending over the ages of 16 to 21 is deep rooted and traditional in England. The best of these apprentices have in the past managed to secure their education by evening study in technical colleges in the most difficult circumstances. Their teachers were commonly drawn from the industry itself—as they still are, very largely. These young men have, by determination and native ability, achieved the highest positions in the industry and profession. For such apprentices or learners a scheme has been in operation for some 25 years which merits attention. It is a scheme of education sponsored jointly by the Ministry of Education and the professional engineering institutions, under which a youth in industry may obtain a nationally recognised certificate and thus achieve professional status. The first award, the Ordinary National Certificate, is obtainable after three years of part-time study from the age of 16; and the second, the Higher National Certificate, requires a further two years. The standard reached in the Higher is that of a pass degree, but of course on a narrower educational front.

The scheme has two cardinal features. Firstly, the college courses are framed to take account of the type of

requirements of local industry—while yet containing a definite minima of mathematics and basic science; for example, the bias may lie towards marine or automobile engineering, or towards electrical instruments or power generation, according to the students' industrial needs. Secondly, the examinations are neither wholly internal nor wholly external, but a combination of both; and, moreover, full weight is given to course and laboratory work, and to work done at home. The student who secures his Higher National Certificate is granted exemption by the professional engineering institutions from their associate membership examinations on a subject for subject basis.

This National Certificate scheme has the merit of great flexibility; moreover, it places no upper limit on the standards achieved by particular colleges in special circumstances, *e.g.* where generous release during the day for college work is a feature.

The two pioneer schemes, in Mechanical and Electrical Engineering, have gone from strength to strength throughout the years. The number of candidates and passes for 1945 were approximately:

Mechanical Engineering:	Candidates	8,000
	Passes	4,800
Electrical Engineering:	Candidates	3,000
	Passes	2,000

These figures are for both Ordinary and Higher National Certificates. The passes for Higher National Certificates alone in both branches were 2,300. (This number is swollen by a war-time intensive scheme and the average normal total would be about 1,500.)

Not all of these 2,300 will achieve positions as professional engineers; but it can be said that they have had the basic education for such positions and that the rest depends largely upon their own initiative.

The scheme has been extended in recent years in association with the Institution of Civil Engineers and the Institution of Productive Engineers. It should perhaps be said that the Institutions of Marine and Automobile Engineers and the Royal Aeronautical Society associate themselves with the Institution of Mechanical Engineers in the general scheme.

The recent developments in the field of Production Engineering are perhaps worthy of comment. These had their origin in the recognition of the growing importance of the problems of manufacture, as distinct from design, and the fact that it was realised that only a small percentage of Higher National Certificate men would be concerned later with design. The first task was to define the essntials of a production engineer's requirements and then to provide a training which would cover them. The courses devised have a common basis of mathematics, applied mechanics, drawing, and technology, leading on to further studies in groups of associated subjects, *e.g.* metrology, jig and tool design, machine tools, welding technology, foundry practice, plastics technology and so on. The College workshop is used for experimentation rather than manipulation.

The development of *post* Higher National Certificate Courses has great possibilities. Such subjects as Industrial Administration, Production Control, Motion and Time Study, etc., which require some maturity of mind, come well at the end of the Certificate course and are increasingly popular. The additional subjects are endorsed on the student's certificate.

The virtues of the National Certificate scheme are fully recognised by

British industry. In recent years the practice of the day-time release of young workers has been greatly extended. This release may be one day, two half days, or two days per week; alternate weeks; or one month in three.

Summary of the General Picture

To summarise, then, technical education for engineers in the United Kingdom lies in two clearly distinguished fields.

On the one hand: the pre-industrial university training, followed by, in many cases but not all, a period of works pupilage. The advantage here is that the scientific training can be thorough, both wide and deep; the disadvantage, that contact with productive industry is deferred over-long.

On the other hand: the concurrent works-college training and education over a long period, usually 5 years at least. The advantage here is that works practice is assimilated during impressionable years, while technical education is also proceeding; the disadvantage is that the time for educations is all too short with the result that the treatment of the fundamental sciences and mathematics has to be adjusted accordingly.

The first kind of training suits the "student" type, *i.e.* the boy who is at home with the abstract, as against the concrete. The other kind suits the more practically minded youth who itches to get to work with his hands at about 16 and who learns better if the subject has an obvious practical application; it may also better suit the late developer. Both types have their place in industry, and both require to have before them the ultimate goal of professional rank and employment. The entrants to the professional engineering institutions are drawn from both streams and contribute effectively to a balanced whole.

The foregoing treats of one block only of technical education and training in the United Kingdom, that for the potential professional engineer. Other interesting sections are, at the lower end, the courses for craftsmen, supplementary to works training; and at the upper, the newer projects for advanced work in a particular field, *e.g.* the College of Aeronautics, the project for which has already been fully reported in the American press.

Like most English organisations, that for the training of engineers is neither regimented nor uniform. It has the appearance of being loose, unorganised, and to some extent unnecessarily varied and complex. It is probably capable of improvement.

One of the principal recommendations in the Report of the Percy Committee, was that Regional Advisory Councils should be established throughout the country to co-ordinate the technological studies in Universities and Technical Colleges; and, further, that the Advisory Councils should create, as an integral part of the regional machinery, Regional Academic Boards of Technology composed of the academic heads of universities and technical colleges and of members of their teaching staffs. It would be the function of the Academic Boards to advise the Governing Bodies of the participating institutions, and the Regional Advisory Councils, on the development and co-ordination of higher technological studies throughout the region. Industry would, of course, be represented in the regional organisation as a whole.

This recommendation shows the trend of opinion and indicates a possible major line of development in technical education generally.

The Builders of the Bridge

The Story of John Roebling and his Son

By D. B. STEINMAN

(Published by Harcourt Brace and Company, New York)

By JOHN CHARLES RIEDEL

Chief Engineer, Board of Estimate, Member, City Planning Commission, City of New York

The life of a man born in the medieval walled town of Mühlhausen in Thuringia in 1806, during Napoleon's advance into Europe, has been woven into a fascinating story by the author, David B. Steinman, Doctor of Philosophy, and himself one of the foremost bridge builders of our era. The story concerns the designers and builders of that noble structure, the Brooklyn Bridge, spanning the East River between what were the cities of Brooklyn and New York, and now, since the creation of Greater New York, the Boroughs of Brooklyn and Manhattan. The author grew up in the shadows of the Bridge and his early life was strongly influenced by the majesty of the towers, the details of construction, the anchorages, the slip joint at midspan, the machinery of the cable railway and the magic of the radiating stays and the strength of the cables. Indeed this strong influence led the author to his life work, that of a builder of bridges. As a partial discharge of the debt of inspiration, the biography of the Roeblings was written.

Undoubtedly the debt of inspiration was great, if judged by the pages of the book. The book is easy to read and holds one's attention constantly. The reviewer has been so strongly impressed that this outline is written with the hope that all young engineers, both those in training and those who have entered the engineering profession, will read and re-read this book so that they may absorb the story of one of the most fascinating biographies that has appeared. Older engineers will find the book to be of surpassing interest. They will be proud to be members of the engineering profession which developed men like the Roeblings, who carried on under the most adverse conditions to the successful completion of what was described in the 1880s as another Wonder of the World.

The story weaves in the history of members of the Roebling family, and were it not for the title one would fancy that the book was a novel of the most pleasing nature.

John Roebling was one of five children of a talented mother and a stolid, phlegmatic father. Four of the children patterned after the father, but John possessed his mother's active mind, quick intelligence and nervous energy. Through her efforts it became

possible for John to receive training and education which fitted him for his life work. The boy's early life was spent under maladjustments of war-torn Europe, but notwithstanding these drawbacks the boy advanced early through the public school of Mühlhausen and into the Gymnasium, the equivalent of our High School. Here he formed the friendship of a lad who, like himself, excelled in mathematics. With his friend's help he prepared for the "builder's examination," which he passed successfully and received an official certificate as a "Baumeister" or Master Builder, at the early age of fourteen. He never completed his courses at the Mühlhausen Gymnasium as his interests were centered in mathematical subjects and technology. He had little liking for the Latin and Theology of the school curriculum. He followed the advice of a former schoolmate and went to the nearby city of Erfurt where he studied at a private school conducted by a famous mathematician. The boy completed his studies at Erfurt when he was seventeen, and through the sacrifices of his mother he went to the foremost engineering school in the world at that time, the Royal Polytechnic Institute in Berlin. While at the Institute he studied under the celebrated Professor Eytelwein, who was the authority on hydraulics and dikes. He also studied foundations and bridge building under Professor Dietleyn, whose stimulating lectures on bridge construction fascinated John. At the Institute he met and studied under the world-famous philosopher, George Wilhelm Hegel. These teachers influenced the thinking of John Roebling to a most marked degree and led to the seeking of a new liberty in the land of the future—America—"the land of hope for all who are wearied of the historic armory of old Europe."

John Roebling passed his final examination with high honors and received the degree of Civil Engineer. He was highly trained in mathematics, engineering and architecture, and was also a skilled linguist, a scholar in history and an accomplished musician.

Roebling was twenty years old when he began his professional career. Opportunities in Germany in the 1820s were limited. The regime was autocratic and private enterprise was practically non-existent. He obtained his first job as Surveyor and Assistant Engineer with the Prussian Government on building of roads and small bridges in Westphalia. He soon discovered that Germany was no place for new ideas, and after three years of work sought to gain new freedom of opportunities. There was much unrest in Germany following the Napoleonic era and groups of men and women were emigrating to America as the Land of Hope. A new revolution was under way and a new nation was born—Belgium. Prussian repression bore down again and it was made illegal for a skilled workman or a trained technician to leave Germany. The oppression of the government, burdensome before, now became unbearable and Roebling and some of his friends organized a colonizing party to go to America. His party was watched constantly and every move was made with the greatest caution and secrecy. He had been marked by the police as the quiet but ardent ringleader of the liberals and was saved from arrest only because of the personal respect and secret sympathy of the mayor.

John Roebling and his friends departed from Mühlhausen on May 11, 1831, for Bremen. John's mother ac-

companied the party to Bremen and as the vessel was sailing away she suffered a heart attack from which she did not recover. She lived long enough, however, to receive word that her son had arrived safely in America. The voyage to America was prolonged by storms, calms and head winds and the arrival at Philadelphia after seventy-six days occurred on August 6, 1831.

The year 1831 was important in the history and development of the United States. The first train to be drawn by a steam locomotive was made in that year. The Government under President Jackson had just authorized projects for roads, canals and railroads amounting to the then staggering sum of ninety-six million dollars. The Erie Canal had been in operation six years. The country was ready to embark on large engineering ventures and John Roebling believed there were opportunities for the exercise of his talents.

Roebling and his small band of followers remained for several weeks in Philadelphia and then left, travelling through the wilderness until they finally reached Pittsburgh, then a new town. The country was wild and isolated. Roebling made a survey of the country and at length purchased a tract of land of 1,600 acres upon which the small company settled, and which was named Saxonburg. Each settler had a farm extending from the center of the community to the foot of the slope, Water Street. Roebling felt, however, that land-clearing and farming were not the kind of work for which he had prepared, although the hard outdoor life agreed with him. The small company was augmented by another group of settlers, among whom was Ernst Herting, his wife and three daughters. One of the girls was Johanna Herting, whom Roebling married in 1836 and who was an ideal wife for the young pioneer.

In 1837 there was born to the Roeblings a son, who was named Washington Augustus Roebling. Father and son were destined to become the famous bridge engineers of the nineteenth century.

For six years John Roebling carried on in the little settlement until he felt his obligation to his fellow colonists had been fulfilled. Through rather pathetic but providential circumstances he was offered employment on the Sandy and Beaver Canal. This was followed by engagements to make location surveys for a projected railroad across the Allegheny Mountains, and it is interesting to note that the pioneer location developed by Roebling for the State was followed in part for the main line of the Pennsylvania Railroad. While he was engaged in these surveys his active mind was occupied by mechanical inventions which he patented, and in engineering works—canals, river improvements, portage railroads and steam railroads.

Portage inclines had been devised in order to haul cargoes and boats over mountains separating navigable streams. Hemp ropes were used to haul these cargoes and boats, and frequently the hemp ropes failed, with consequent damage. Roebling felt that a rope made out of iron wire could be made with lessened cost and increased strength and efficiency, and the first wire rope was made in 1841 for use on the inclined plane railways. The makers of hemp rope were much opposed to the introduction of wire rope and resorted to devious devices to discourage the new invention. Roebling made a wire rope or cable for use on the inclined railway planes of the Pennsylvania Canal. The opposition hired a man to

cut Roebling's cable at a splice, and the cable failed during the test. Fortunately for Roebling's reputation, the sabotage was discovered by one who informed the President of the Pennsylvania Canal Commission of the foul act. This President, after learning of the incident, appointed Roebling as Superintendent of the Inclined Plane Railway. Thereafter Roebling was able to use wire cable with complete success. The wire ropes soon supplanted hemp ropes on other canal portage railways, thereby reducing costs and hazards in carrying boats and cargoes over mountains. The village of Saxonburg became the home of the new industry, which revolutionized the methods of hauling canal boats and portage railways. The field of application soon widened as new uses were developed.

Roebling was now ready for greater achievements and the rebellious liberal, the poetic dreamer, the optimistic pioneer became a personality of the forgotten past in the new grim, hard, determined Man of Iron. He became the apostle of the power of wire and he applied his inventive genius and great vision in the design and construction of a suspension bridge to carry an aqueduct across the Allegheny River at Pittsburgh. The most significant feature was the construction of the cables in accordance with his new ideas. The cables were "solid and compact" and the important improvement of a "continuous wrapping" of wire around the cables was first applied. Roebling also devised and patented a new form of anchorage which was used in all of the bridges he subsequently built.

Following the success of the suspended aqueduct or canal he designed and built under the most adverse circumstances and trying conditions a toll suspension bridge spanning the Monongahela River. This bridge was used for all classes of traffic. Roebling first used on this bridge a system of inclined stays which introduced a strength and rigidity that was new to bridge building. Dr. Steinman writes concerning this:

"The necessity of providing adequate stiffening constructions in suspension-bridge designs was one of the most important lessons that Roebling taught the profession. Earlier spans built by others failed because this essential principle was not realized. And a century later, when bridge engineers—over-confident—forgot the lesson and began to slight this prime requirement that Roebling had established and emphasized, disaster resulted."

The fame of Roebling's work spread and engineers from all over the United States showed marked interest in his accomplishments. He continued with his innovations by the construction of suspension aqueducts over the Lackawaxen River for the use of the Delaware and Hudson Canal, then one of the chief means of transportation. He followed by building suspended aqueducts over the Rondout near its junction with the Hudson, and subsequently he constructed the suspension bridge for the Neversink Aqueduct near Port Jervis. Dr. Steinman writes on page 105:

"For seventy years the Delaware and Hudson Canal served its farsighted purpose. But, like all other intermediate steps of human advance, the canal and its works finally yielded to the inevitable march of progress. On November 5, 1898, canalboat 'Number 1107' was loaded and cleared, and this was the last boat carrying the company's anthracite to pass over the canal. Soon thereafter the entire bed of the canal, the locks, and other works were sold for a nominal sum to

private parties, to be occupied by railway lines and for other uses.

"Following the discontinuance of the canal, the suspension aqueduct over the Delaware River at Lackawaxen, although fifty years old at the time, was promptly converted by its new owners into a highway toll bridge, the bed of the aqueduct serving as the roadway for the viaduct. The ancient structure, built a century ago for other duty, is still in use, carrying modern automobile and motor-truck traffic.

"The other structures of the old Delaware and Hudson Canal were taken down for salvage. Here and there an undemolished lock wall, aqueduct abutment, old anchorage and cable, or a section of the abandoned canal prism are the only physical vestiges of that famous waterway of a bygone age.

"In 1921 some samples of the wire were taken out of the old cables left in the abandoned ruins of the High Falls aqueduct. Laboratory tests showed a tensile strength even higher than the original strength reported by Roebling. The wires were of wrought iron, and although they were ungalvanized, they showed no material corrosion after their seventy-two years of service and exposure."

Roebling throughout his life showed a far-seeing perception of future developments and was a pathfinder and prophet of progress. In an article published in the New York *Journal of Commerce* he wrote that a transatlantic cable was a highly necessary and perfectly feasible project. Four years later Cyrus W. Field became actively interested and began work on the project, which took twelve years before a cable connection was established between Europe and America.

Roebling in 1848 moved his activities to Trenton, New Jersey, and there established a manufacturing industry that revolutionized the making of wire and wire rope for many applications in civilized life, such as elevators in apartment houses, office and business buildings; in cableways for transportation of logs in the forest of the northwest; in haulage in tunnels and mines and shafts; in shipping and dredging. It is not easy to grasp how much the world is indebted to the invention and development of wire rope.

Notwithstanding the many activities in which Roebling became interested, he constantly looked ahead to the construction of suspension bridges of larger and larger spans, and the opportunity came when a railroad suspension bridge was projected across Niagara gorge. An engineer-contractor contemporary of Roebling had undertaken to build a railroad suspension bridge across Niagara and had failed to complete his contract. Roebling was called in and after four years of work under trying conditions completed this first railway suspension bridge in the world. Roebling wrote at the time that professional and public opinion had been averse to suspended railway bridges, but that he had demonstrated that *weight, girders, trusses* and *stays* made it possible to apply the suspension bridge to railway traffic.

While John Roebling was developing a new science in bridge building, his son, Washington A. Roebling, was growing into manhood and was attending the Rensselaer Polytechnic Institute, from which he was graduated in July 1857 with the degree of Civil Engineer. It is interesting to observe that his senior thesis was on "Design for a Suspension Aqueduct." The young engineer, following graduation, returned to Trenton and took up work in the Roebling mill. He assisted his father in the erection of a new suspension bridge over the Allegheny River at Pittsburgh during the trying times that preceded the secession of the south-

ern states. The Allegheny Bridge, when it was finished in 1860, was generally regarded as the finest in the world.

From 1846 to 1856 the people of Cincinnati, Ohio, and of Covington, Kentucky, were agitating for a bridge across the Ohio River. In 1856 John Roebling was called to Cincinnati to take over the design and construction of a suspension bridge for mixed traffic. Financial stresses and adverse weather conditions delayed the work of construction, and with the opening of hostilities between the States in 1861, all work of bridge building was suspended.

Young Roebling enlisted as a private in the New Jersey State Militia following the call of President Lincoln for 75,000 volunteers. Looking for more active service, he secured a discharge from the New Jersey Regiment and immediately enlisted as a private in the Ninth Regiment, with which he saw action at the front. He advanced in rank and within a year was a lieutenant. In 1862 Lieutenant Roebling was transferred to the staff of General McDowell and took up engineering duties, principally on the design and construction of suspension bridges for military purposes. He became a captain in 1863, attached to the staff of Major General Warren. This assignment led to meeting Emily Warren, his future wife, while she was on a visit to her brother, General Warren. In 1864 Captain Roebling was promoted to the rank of Major and Aide-de-Camp on General Warren's staff. For his brave conduct before Richmond, Major Roebling was breveted Lieutenant Colonel, U. S. Volunteers. Early in 1865, after the fighting was over on the front on which he was engaged, he was given his honorable discharge from the Army in order to go to Cincinnati and assist his father in the work of constructing the suspension bridge which had been discontinued at the opening of the war. In March 1865 Washington Roebling was given the full brevet rank of Colonel, U. S. Volunteers, for "gallant and meritorious service during the war."

The next two years saw the work of building the Cincinnati-Covington suspension bridge continued to completion. The bridge was placed in service on New Year's Day, 1867, and created favorable comment from all over the country and from England. Dr. Steinman quotes from a report by the Chief Engineer of the United States Army covering the history and description of the bridge: "It is a magnificent structure, and one of which the citizens of the two cities are justly proud." He also quotes an editorial in *Engineering*, the leading technical journal published in England, which recognized the outstanding character of the achievement:

"The largest existing span of a suspension bridge is that of 1057 ft. over the Ohio River at Cincinnati, lately completed from the plans of Mr. John A. Roebling and under the superintendence of his son, Colonel Washington A. Roebling. This bridge is undoubtedly the finest work, structurally and architecturally, of its class."

While John Roebling had been busy with the construction of the Niagara Suspension Bridge and the suspension bridge across the Ohio at Cincinnati, he had been giving thought to a still greater accomplishment, namely, that of spanning the East River separating the cities of New York and Brooklyn. As early as 1852 he proposed such a bridge, but many years passed and the Civil War intervened before the matter

developed to the point where the civil leaders of Brooklyn met in conference in a house near what is now Owl's Head Park in Bay Ridge, Brooklyn. From that historic meeting developed the movement, led by Senator Murphy, a former Mayor of Brooklyn, and William C. Kingsley, a prominent contractor and leading business man. Legislation was obtained and in 1867 John A. Roebling was appointed Chief Engineer of the proposed bridge. The work was financed by a company consisting of the most important citizens of New York and Brooklyn. Surveys were begun by Roebling in the middle of 1867, and shortly thereafter he sent his son, Colonel Washington A. Roebling, to Europe to make a thorough study of the then newly developed pneumatic method of sinking caisson foundations. He remained for a year and visited England, France and Germany, in which three countries important engineering works were in progress.

John Roebling proceeded with his plans and selected the line to City Hall Park in New York because it afforded the best grades and the best accommodations for traffic. In his initial report to the Trustees of the Brooklyn Bridge he laid stress upon the wide elevated promenade that has become famous to millions who have enjoyed it through the sixty years that the bridge has been in service. In this report he also made the revolutionary proposal to use *steel* wire instead of iron wire for the cables. This provoked much discussion, and had anything gone wrong because of the decision Roebling's reputation would have been wrecked. Dr. Steinman presents on pages 310 and 311 of his book:

"In his plans for his bridge Roebling utilized the cumulative wisdom of all his prior contributions to the art, so as to secure rigidity and stability in a measure never before attained. Profiting by the sad experiences of others whose spans had been destroyed by vibrations or had been blown down by the wind, the master builder developed a design that would defy the elements and stand immovable through years to come. The features by which this enduring resistance was secured, he described in his classic report: 'To guard against vertical and horizontal oscillations, and to insure that degree of stiffness essential to meet the effect of violent gales in such exposed situation, I have provided six iron trusses, which run the whole length of the suspended floor from anchor wall to anchor wall. . . . A most effective framing is thus obtained, which will be found to possess ample stiffness even in the greatest emergency. I am not disposed to underrate the great force of a severe gale, and I am also fully aware that herein lies the great danger to all suspension bridges of ordinary design. But my system of construction differs radically from that formerly practiced, and I have planned the East River Bridge with a special view to fully meet these destructive forces. It is for the same reason that, in my calculation of the requisite supporting strength, so large a proportion has been assigned to stays in place of cables.'

"Perhaps the most distinctive feature of the Brooklyn Bridge is the system of inclined stays radiating downward from the tops of the towers to the floor of the span. The magic of the resulting web-like tracery of lines has been the delight of artists and poets, and of all who love beauty. But these radiating lines were not gratuitously added for artistic effect; the genius of Roebling introduced them primarily for the critical function of adding rigidity to the span, and then took advantage of the additional load-carrying capacity which they incidentally supplied. This contribution to the strength of the bridge was explained in simple terms by the designer: 'The floor, in connection with the stays, will support itself with-

out the assistance of the cables. If the structure is viewed in this light, it will make a different impression upon those who are in the habit of associating with the idea of a suspension bridge the picture of a free-swinging pendulum. . . . The supporting power of the stays alone will be 15,000 tons, ample to hold up the floor. If the cables were removed, the bridge would sink in the center, but would not fall.'

"Half a century or more before other bridge engineers learned the lesson, Roebling's clear thinking had crystallized the basic principle governing the economy and rigidity of suspension designs—namely, that any desired degree of stiffness can be secured if one is willing to pay for it and, conversely, excessive economy in first cost may mean dangerous reduction in stability. As he lucidly expressed it: 'If a rigid economy was to be exercised for want of capital, less strength and stiffness might answer. By a reduction of weight and of strength, a great deal of expensive material and work might be saved. But in the same proportion would the stiffness of the work be also decreased, and its safety in the case of a great hurricane less insured.'"

The dominant feature of the finished bridge would be two towers which would be based on foundations that would be laid on solid rock if such could be found at reasonable depth.

Roebling also wrote in his report: "The contemplated work, when constructed in accordance with my designs, will not only be the greatest bridge in existence, but it will be the great engineering work of this Continent and of the age. Its most conspicuous feature—the great towers—will serve as landmarks to the adjoining cities, and they will be entitled to be ranked as national monuments. As a great work of art, and as a successful specimen of advanced bridge engineering, this structure will forever testify to the energy, enterprise, and wealth of that community which shall secure its erection."

The general public of New York and Brooklyn were incredulous and Horace Greeley of the New York *Tribune* and Mayor Kalbfleisch of Brooklyn expressed doubts that a bridge of such staggering proportions could be built. But Roebling stood steadfast, his Board of Trustees expressed their confidence in him, and the work went on.

In the early summer of 1869 a final detailed survey was under way. John Roebling was taking observations to determine the exact location of the Brooklyn tower. He was standing on a cluster of piles at the rack of the Fulton Ferry slip receiving signals from his assistant who was on the distant New York shore. He was oblivious that a ferryboat was entering the slip. The fender rack was forced against the piles and Roebling's foot was caught and crushed between the timbers. Immediate medical and surgical attention was given, but lockjaw set in, resulting in his death on July 22, 1869. Robeling was sixty-three years of age when he died. In the last few years of his life he felt physically spent. "He had exhausted his vitality on his unstinted outpouring of energy into his work."

While the Brooklyn Bridge is the finest monument to his memory, another monument was erected in Trenton in 1908 and the speaker of the day said:

"I am expected, by those having these ceremonies in charge, to translate into words what the sculptor has so admirably expressed in bronze, namely the type and quality, the idiosyncrasy of your famous fellow townsman. But words are too plastic for such a task. As if his nature

had been subdued to what it worked in, the Iron Master of Trenton was a man of iron. Iron was in his blood, and sometimes entered his very soul. . . . John A. Roebling as he was, as you knew him, head bared to the blows of fortune or the storms of heaven, eyes fixed unwaveringly on whatever object he had in hand, poised, confident, unyielding, imperious and proud—John A. Roebling is there—seated forever on yonder pedestal."

With the passing of John A. Roebling it seemed that it would be impossible for the bridge to be built. Roebling had been its designer but was much more. He had furnished the inspiration and the vision and had conceived the whole and knew every part. Dr. Steinman presents on page 323:

"By destiny or prevision the master builder had prepared a deputy who was indeed a part of himself—his own son, Colonel Washington A Roebling. This young but able engineer had been trained and prepared for this task. He had been given the best engineering education of the time; he had received his practical training under the greatest bridgebuilder of his day—his own father; and his own judgment, initiative, and courage had been tried and tested on the battlefield.

"For years he had shared his father's professional confidence and labors. They had worked together on the construction of the Pittsburgh-Allegheny bridge and the great Cincinnati span, and the disciple had become thoroughly schooled in the master's methods. And in the Civil War he had devised and built his own suspension bridges under conditions testing both resourcefulness and fearlessness.

"When the elder Roebling began planning the Brooklyn Bridge, the son took an immediate interest in the great adventure. He helped his father in the preliminary studies; and then he journeyed to Europe, visiting all the important engineering and metallurgical works and studying caisson work and the fabrication of the new structural material, steel. With the mass of data and information he had collected, he returned to America to serve as his father's aide for twelve months before the latter's death. He was thoroughly familiar with the plans for the bridge, having helped to create them.

"And, most important of all, Washington Roebling had the endowments of character and personality that the grave responsibility demanded. He had inherited not only his father's true engineering instincts but also his concentrated devotion and unconquerable tenacity of purpose.

"To this son the great engineer on his deathbed turned over the completion of the task. The following month—August, 1869—at a meeting of the directors Colonel Washington A. Roebling was officially appointed to succeed his father as Chief Engineer of the work.

"Courageously and loyally the son assumed the gigantic responsibility of carrying forward the construction of this, his father's greatest dream. To this consecrated task the young engineer gave all he had—his health, his strength, his career.

"He resigned as president of the wire company at Trenton to devote all his time and energy to the bridge, and his two brothers, Ferdinand and Charles, took charge of the wire-rope plant. From that day until the job was ended, Washington Roebling lived only for the Brooklyn Bridge.

"But many were the problems, the difficulties and the struggles which fell to the young chief engineer during the building of the great span. Tragedy, stark and grim, marked both the commencement of the project and its consummation. In the approximately thirteen years from the actual beginning of the work, when laborers started to clear away the site for the Brooklyn tower on January 2, 1870, to the opening of the structure to the public on May 24, 1883, deaths and casualties were many. Into the construction of the monumental span went blood, sweat and anguish in equal meas-

ure with cement, stone, steel and treasure."

The building of the caissons for the towers presented many new, increasing and never ending difficulties. Boulders were encountered and Colonel Roebling resorted to the new idea of blasting within the caissons. He spent many hours and days within the chambers and at length conquered the many difficulties and setbacks which had appeared. On one occasion the "Big Blowout" occurred when the compressed air suddenly blew out through the south shaft. Fortunately no one was in the caisson when the accident occurred and within a little while work proceeded within the caisson. On another occasion a fire took place in the caisson which was so serious that three months were required to repair the damage. Another incident took place when suddenly two supply shafts blew out. Colonel Roebling was trapped in the caisson with several others and due to his presence of mind the supply shaft doors were closed and order was restored.

During the sinking of the caissons, men were obliged to be under air pressures sometimes thirty-five pounds per square inch, and many became subject to attacks of the "bends." Several fatal cases developed and Colonel Roebling did everything that medical science of that time could prescribe. Colonel Roebling wrote: "The few cases of death that have occurred can in but two instances be charged to the effects of the pressure. It is true that scarcely any man escaped without being somewhat affected by intense pain in his limbs or bones, or by a temporary paralysis of arms and legs; but they all got over it, either by suffering for a few days outside, or by applying the heroic mode of returning into the caisson at once, as soon as the pains manifested themselves, and then coming out very slowly." In an official report on the progress of the work at this time he stated: "The labor below is always attended with a certain amount of risk of life and health, and those who face it daily are, therefore, deserving of more than ordinary credit."

Dr. Steinman writes on page 367:

"One afternoon in the early summer of 1872 Colonel Roebling had to be carried out of the caisson, nearly insensible, a victim of the dread caisson disease. All night his death was hourly expected.

"In a few days he rallied and, mustering all his reserve of strength, he attempted to return to work. But he again collapsed and had to be brought home.

"At the age of thirty-five his days of physical exertion were ended. He remained painfully paralyzed—doomed to lifelong suffering—with progressive blindness and deafness setting in, vocal cords affected, and every nerve and muscle tortured with pain.

"Thenceforth this man, who had been full of life and hope and daring at the inception of the work, was a crippled invalid, confined to his home. Just as his brilliance as an engineer was at its height, and just as his masterwork was passing its crisis, he was struck down."

And again on page 369:

"His wife was as rare and strong as the man she tended. She met the emergency by becoming his capable aide. Instead of crying hysterically over her husband's misfortune and sinking down nerveless and helpless into the privileged softness of her sex, she set herself at once to the task of acquiring the knowledge necessary to become a real helpmeet to him in the critical situation. Under his guidance she studied higher mathematics, the calculation of catenary curves, strength of materials, stress analysis, bridge specifications, and the intricacies of cable con-

struction; and she applied her new education to the problems of the bridge. She grasped her husband's ideas and she learned to speak the language of the engineers. She made daily visits to the bridge to inspect the work for the Colonel and to carry his instructions to the staff. She became his co-worker and his principal assistant—his inspector, messenger, ambassador, and spokesman—his sole contact with the outside world.

"But in developing scientific and technical skills to meet the emergency, she did not sacrifice her womanly qualities. She remained the comforting companion and tender nurse. As Thomas Kinsella, one of the bridge trustees and editor of the *Brooklyn Eagle*, remarked at the time: 'The most abstruse study has not interfered with Mrs. Roebling's ministrations at her husband's bedside. If he is restored to health, it will be largely through her patient and intelligent attendance upon him, and Colonel Roebling will be indebted to his noble wife even as the people are.'

"In the summer of 1873, on his physician's advice, the Colonel went abroad—to Wiesbaden—for several months in a vain quest to restore his shattered health, but on his return he suffered another attack of acute prostration.

"During the following years the Chief Engineer continued to superintend construction from his sickroom. An artist of the day has left us a drawing, published in a popular magazine, depicting the paralyzed bridgebuilder seated at his widow, gazing wistfully at the unfinished structure in the distance; his field glasses rest on the sill; and on a table near by is his beloved violin, its strings now mute—for never again will the invalid's fingers be able to produce the music he loved.

"The Colonel's continued planning and direction of the work, despite constant pain and a nervous collapse which would have cut off an ordinary man from mental as well as physical activity, was an outstanding triumph of consecration and will power. His own self-sacrifice inspired the most devoted loyalty in the corps of engineers about him, and they directed all their energies to carrying out his wishes. Not the slightest advantage was ever taken of his illness to deviate from the letter or spirit of his plans; and Colonel Roebling, physically helpless, away from the work, always remained complete master of the enterprise. Like a wounded general who directs a battle from a hilltop, Washington Roebling issued his orders and superintended the completion of the bridge.

"Through field glasses, he watched the building of the towers and later the stringing of the cables. Though he was absent in body, it was still his spirit that prevailed and his brain that directed the work. The bridge was his—by right of inheritance, by his own labors, and by his own sacrifice."

Colonel Roebling was not only beset by physical hardships during the ensuing years but he was confronted with political corruption, civic jealousies, lack of funds, injunction proceedings and dishonest contractors. The two towers required five years to build, one year of which was consumed in sinking and filling the foundation and four years in completing the masonry.

The preparatory work for cable spinning was begun in the summer of 1876. The story of the spinning of the cables is one of entrancing interest and carries one from the early work in 1876 to 1878. The spinning of the cables was completed in October 1878 and then the tedious work of drawing all the strands of a cable together to a true cylindrical form by means of powerful squeezers was begun. The cable wrapping was then applied.

Many of the people of New York showed their opposition to the work by opposing an increased appropriation required to complete the bridge, and controversy and litigation arose which required many months to settle. How-

ever, the differences were all settled and in December 1881 the floor beams were completed and Mrs. Roebling, the assistant engineers and eleven of the trustees walked across the span on a footpath of planks.

It developed in 1881 that about one thousand tons of additional steel would be needed as a result of changes in design required to permit a train of heavy railroad cars to cross the bridge. Again there was a storm of criticism and the *Engineering News,* the country's leading construction journal, published a vigorous editorial defending the engineering project, as follows:

"The cost of a few additional tons of steel, over which the shortsighted are howling as an evidence of mistaken calculation, is in reality but a healthy outgrowth of expanded ideas of the importance of this structure. In the fourteen years which have elapsed since the bridge was designed, enormous strides have taken place, and are now taking place daily, in the volume, weight and character of railroad intercommunication. Such things, for instance, as Pullman cars, weighing over thirty tons, had never been thought of at that day. The bridge, when designed, was in advance of the highway bridges of the day, but its purpose was but that of a highway bridge. City travel, as then conducted, required cars of but two or three tons weight. Without any disparagement to the talents of the elder Roebling, we believe that it is entirely owing to what the *Times* is pleased to consider as the stupidity of the present engineers, that the structure will be capable of withstanding all the strain which by any possibility it can be subjected to; and when completed we are confident it will reflect the greatest credit upon all who have been instrumental in perfecting it, with an eye to its future needs and in disregard of the clamors which it might provoke."

Charges were brought by the enemies of the project and Colonel Roebling wrote in June 1882 to the Board of Trustees, in answer to a request that he appear before them:

"I am not well enough to attend the meetings of the Board, as I can talk for only a few moments at a time, and cannot listen to conversation if it is continued very long. My physicians hope that living out of doors and away from the noise of a city may lessen the irritation of the nerves of my face and head. I am now able to be out of my room occasionally. I did not telegraph you before the last meeting that I was sick and could not come, because everyone knows I am sick, and they must be as tired as I am of hearing my health discussed in the newspapers.

"I believe there is not a day that I do not do some sort of work for the Bridge. . . . My assistants do the work assigned to them with perfect confidence that they can always refer to me for any advice or assistance they need. The work to be done this summer is very plain routine. There is nothing to be done that has not been done before, and the interests of the Bridge do not suffer in any way from my not being there. If the Edgemoor Iron Company will furnish the steel as fast as we need it, the work will go on all right and without delay.

"It is very important that authority be given me at your next meeting to advertise for the iron for the elevated termini, the spruce planks for the floors, the steel rails for the tracks on the Bridge, and the paint. Specifications for all these things are now ready, and they should be obtained as soon as possible, so that they may be ready when we want to use them.

"I shall be most highly honored to be present at meetings of the Board as soon as I am well enough to be of any use there."

The Board of Trustees considered a proposal to supplant Colonel Roeb-

ling as Chief Engineer but did not act upon the proposal. Colonel Roebling through his wife appealed to the American Society of Civil Engineers, then in session, and through the eloquence of her appeal the backing of the profession was secured and the confidence of the public won.

The work was completed and the formal opening arranged for May 24, 1883. The work had required 13 years to build and it had cost over twenty lives. "Orators and writers paid their tributes to the significance of the achievement. It was hailed as a mighty engineering feat—the longest span in the world—the longed-for link between New York and Brooklyn—the promise of a Greater New York."

The paralyzed engineer watched the celebration through his field glasses and could only read the next day the dedication of the orator, the Honorable Abram S. Hewitt, later Mayor of New York. He said:

"When we turn to the graceful structure at whose portal we stand, and when the airy outline of its curves of beauty, pendent between massive towers suggestive of art alone, is contrasted with the over-reaching vault of heaven above and the ever-moving flood of waters beneath, we are irresistibly moved to exclaim, 'What hath *man* wrought!'

"Man hath, indeed, wrought far more than strikes the eye in this daring undertaking, by the general judgment of engineers, without a rival among the wonders of human skill. . . .

"But the Bridge is more than an embodiment of the scientific knowledge of physical laws. It is equally a monument to the moral qualities of the human soul. It could never have been built by mere knowledge and scientific skill alone. It required, in addition, the infinite patience and unwearied courage by which great results are achieved. It demanded the endurance of heat, and cold, and physical distress. Its constructors have had to face death in its most repulsive form. Death, indeed, was the fate of its great projector, and dread disease the heritage of the greater engineer who has brought it to completion. The faith of the saint and the courage of the hero have been combined in the conception, the design and the execution of this work.

"Let us, then, record the names of the engineers who have thus made humanity itself their debtor for a successful achievement, not the result of accident or chance, but the fruit of design, and of consecration to the public weal. They are: *John A. Roebling*, who conceived the project and formulated the plan of the Bridge; and *Washington A. Roebling*, who, inheriting his father's genius, and more than his father's knowledge and skill, has directed this great work from its inception to its completion. . . .

"During all these years of trial, and false report, a great soul lay in the shadow of death, praying only to stay long enough for the completion of the work to which he had devoted his life. I say a great soul, for in the springtime of youth, with friends and fortune at his command, he braved death and sacrificed his health to the duties which had developed upon him, as the inheritor of his father's fame, and the executors of his father's plans. . . .

"But the record would not be complete without reference to the unnamed men by whose unflinching courage, in the depths of the caissons, and upon the suspended wires, the work was carried on amid storms, and accidents, and dangers sufficient to appall the stoutest heart.

"One name, which may find no place in the official records, cannot be passed over here in silence. With this Bridge will ever be coupled the thought of one, through the subtle alembic of whose brain, and by whose facile fingers, communication was maintained between the directing power of its construction and the obedient agencies of its execution. It is thus an everlasting monument to the self-

sacrificing devotion of woman. The name of Mrs. Emily Warren Roebling will thus be inseparably associated with all that is admirable in human nature, and with all that is wonderful in the constructive world of art."

One after the other the following speakers added their words of acknowledgment and praise. From one who had been intimately identified with the bold enterprise from its inception, the Honorable William C. Kingsley, the hushed audience heard the story of the planning and the building, the heroism and the sacrifice:

"With one name, this Bridge will always be associated—that of *Roebling*. At the outset of this enterprise we were fortunate to secure the services of John A. Roebling. . . . While testing and perfecting his surveys . . . the man who designed this Bridge lost his life in its service. He was succeeded by his son, Colonel Washington A. Roebling. . . . Down in the earth, and under the bed of the East River . . . within the caissons . . . always on hand at the head of his men to direct their efforts and to guard against any mishap or mistake which might have proved disastrous. . . . Colonel Roebling contracted the mysterious caisson disease. . . . For many long and weary years this man, who entered our service young and full of life, and hope, and daring, has been an invalid, confined to his home. He has never seen this structure as it now stands, save from a distance. . . . But every step of its progress he has directed. . . . Colonel Roebling may never walk across this Bridge, as so many of his fellowmen have done today, but while this structure stands all who use it will be his debtors."

Dr. Steinman concludes this most interesting story of the Builders of the Bridge with the following:

"Twenty-five years later a monument is being unveiled to the master builder, John A. Roebling. Many thousands are gathered to honor the memory of the man. An orator is speaking. The vast audience is hushed, as his words find an echo in every heart. In inspired eloquence, linking the magic of the Bridge with the personality and genius of its creator, the speaker pays Humanity's tribute:

" 'Yes, Brooklyn Bridge is beautiful. All the latent poetry of the mathematician—and in its highest reaches mathematics becomes divinest poetry; all the aestheticism of the architect; all the musician's sensitiveness to harmony; all the mysticism of an idealist philosophy; whatever of faith, feeling, reverence John Roebling cherished in his heart, was here voiced like a ringing cry. As if conscious of his pending doom, his genius stands embodied in this form—an aspiration visible—a soul's bid for immortality.' "

Sections and Branches

The members of the **Kentucky Section** of S.P.E.E. were recently polled concerning their desire to continue as a Section of the Society under the proposed new constitution. The membership voted almost unanimously to disband as a section and to join officially with the Southeastern Section under the new constitution.

The Kentucky Section, therefore, disbanded on April 26, 1946. Unexpended funds in its treasury amount to $3.70 were turned over to the Treasurer of the Southeastern Section.

F. L. WILKINSON, JR.,
Ex-Chairman Kentucky Section.

The **New England Section** has planned its fall meeting to be held at Norwich University, Northfield, Vermont, on Saturday, October fifth.

CARLTON E. TUCKER,
Secretary.

The fall meeting of the **North Mid-West Section** will be held on October 18 and 19, 1946, at Iowa State College. The officers and executive committee of the section are now as follows:

Chairman: L. O. Stewart, Iowa State College
Vice-Chairman: O. Neil Olson, Marquette University
Secretary-Treasurer: E. H. Ohlsen, Iowa State College
Board Members:
Gordon F. Tracy, University of Wisconsin
L. A. Rose, Michigan College of Mining and Technology
R. W. French, University of Minnesota
J. W. Howe, State University of Iowa

L. O. STEWART,
Chairman.

The officers of the **Southeastern Section** elected for the next year are as follows:

Chairman: Joseph Weil, University of Florida
Vice-Chairman: Fred J. Lewis, Vanderbilt University
Secretary: H. G. Haynes, The Citadel

The section accepted the invitation of the University of Louisville to hold their next meeting in Louisville.

23 colleges in the S. E. Section were represented as well as four colleges out of the section. The total registration was 92.

H. GALE HAYNES,
Secretary.

COLLEGE NOTES

C. A. Joerger, **University of Cincinnati** faculty member since 1913, becomes Dean of the College of Engineering September 1, 1946, after serving as Acting Dean from March 1 through August 31, succeeding Robert C. Gowdy. Dr. Gowdy will be on leave of absence during the six months period, retiring September 1 because of poor health. Professor Joerger is a graduate of Stevens Institute, Hoboken, New Jersey, and taught in the Engineering College of Harvard University before coming to Cincinnati where he has been head of the department of mechanical engineering.

Professor Howard K. Justice, University of Cincinnati graduate and faculty member since 1921, effective March 1, 1946, was named to a new position of Assistant Dean and Director of Admissions in the College of Engineering.

The reorganization of the department of petroleum engineering at the **Colorado School of Mines** as the department of petroleum production engineering and the department of petroleum refining engineering has been announced by Ben H. Parker, president of the school.

Heading the department of petroleum production engineering will be Clark F. Barb, now head of the department of petroleum engineering and director of the petroleum research being conducted at the school under the Colorado Industrial Development Research program.

James O. Ball, associate professor of petroleum engineering since 1938, has been named head of the new department of petroleum refining engineering.

A new vice-presidency of **Cornell University** was created by the Board of Trustees at its spring meeting, to be filled by Dean S. C. Hollister of the College of Engineering. Dean Hollister will continue as head of the College of Engineering while assuming new administrative duties. As a vice-president of Cornell, he will be in charge of University development.

The University of Iowa announces the 1946 Management Course devoted to production planning, plant layout, motion and time study, wage incentives and related subjects, June 10 to June 28.

This is an intensive course intended for plant managers, foremen, industrial engineers, methods and time study analysts, cost accountants, and office executives, to be held in Iowa City.

The main objective of American industry has been to make a better product at a lower cost. Ever-increasing productivity per man-hour has enabled us to reduce selling price, improve quality, and pay higher wages in this country.

If we are to continue in this direction industry must use its manpower more effectively than ever before, utilizing the best methods and equipment, planning and controlling production carefully, measuring the operator's productivity accurately and paying the worker in proportion to the product he turns out.

Management in this country *can* pro-

duce a better product at a reasonable cost, and the public has the purchasing power to buy the goods produced. If all industry could but use the best management methods available we could attain a level of productivity undreamed of by most people.

Great advances have been made in management methods and techniques in recent years and it behooves every organization to understand and practice these better methods.

The summer Management Course at the University of Iowa, now in its eighth year, is held especially for people in industry interested in production planning, plant layout, motion and time study, wage incentives and other related subjects. The purposes of the course are:

1. To show how production planning can be coordinated with the various activities of an organization.
2. To provide full understanding of the fundamentals of motion and time study.
3. To present opportunities for counseled application of the principles of production planning and motion and time study to individual industrial problems in the Industrial Engineering Laboratory.
4. To demonstrate ways of instituting training programs in factories and offices.
5. To provide unexcelled opportunity for discussion of problems common to varied industries relative to production planning, motion and time study, and wage incentives.
6. To provide instruction in organizing and presenting ideas orally.

The course will be held under the direction of Ralph M. Barnes, Professor of Industrial Engineering at the University of Iowa, and will be conducted in much the same way as in past years. The course runs from 8:00 a.m. to 5:00 p.m. each day with forenoons devoted to lectures and discussions and the afternoons to laboratory and project work. Professor Barns will be assisted by members and engineers from industry and by members of the University staff.

Expenses

Tuition and Fees

Tuition and Laboratory Fee..$150.00
This includes textbooks, materials and supplies, printed forms, and reprints of articles and papers.

Living Expenses (room only)

University dormitory facilities will be available for those wanting such accommodations. Rates are as follows:

Single room for three weeks..$22.50
Double room for three weeks (per person) 15.00

Hotels in Iowa City are crowded but some rooms will be available. Rates —$3.00 to $4.00 per day.

Noon meal Monday through Friday during three-week course....$15.00
Inasmuch as the weekday luncheon meetings are a part of the course, the University Dining Service will serve the noon meal.

Registration

Advance registration for the course is required, enrollment will be *limited* and applications will be accepted in the order of their receipt. Registration and communications concerning the course should be sent to Ralph M. Barnes, College of Engineering, University of Iowa, Iowa City, Iowa.

It is expected that those attending will be college or university graduates, or their equivalent, since persons of this general level will benefit most from

the course. No certificates or records of previous training will be required of applicants unless they desire college credit for the course.

Tuition and laboratory fee for the three-week course is $150.00, payable at the University Business Office on June 10, 1946.

The Physics and Electrical Engineering Departments of the **Agricultural and Mechnical College of Texas** announce a graduate conference on Electron and Ion Ballistics June 24 to July 6, 1946. Dr. L. Marton, of the Division of Electron Optics of Stanford University will lecture the first and second weeks of the conference and Dr. J. A. Hipple, of the Westinghouse Research Laboratories, will lecture the second and third weeks. The conference is intended to acquaint research physicists and engineers with some of the more advanced phases of contemporary theory determining the movement of electrons and ions in modern electronic equipment, especially mass spectrometers and electron microscopes.

Persons desiring further information on the conference are invited to write J. G. Potter, Head, Department of Physics, or M. C. Hughes, Head, Department of Electrical Engineering, Agricultural and Mechanical College of Texas, College Station, Texas.

The **University of Texas** has recently established a new research laboratory known as the Defense Research Laboratory, which is one of a series of such organizations in universities and in industry operating under a Section T contract with the Bureau of Ordnance. Fundamental problems relating to certain forms of guided missiles comprise the research goal of the new organization.

Major fields of research which are combined in the work of the Defense Research Laboratory are electronics, chemistry, optics, thermodynamics, acoustics and mathematics.

Dr. C. P. Boner, Professor of Physics at the University, who has been on leave of absence as Associate Director of the Underwater Sound Laboratory of Harvard University, is the Director of the Defense Research Laboratory. Dr. M. J. Thompson, Professor of Aeronautical Engineering at the University, who has also been on leave of absence as Group Supervisor for Aerodynamics at the Applied Physics Laboratory, Johns Hopkins University, is the Associate Director. The research staff includes members of the University academic staff from the College of Engineering and the Departments of Physics, Chemistry and Mathematics. This group is augmented by additional full-time research staff members who are being recruited from other laboratories engaged in similar research. The staff numbers approximately 75 people.

The Laboratory is housed in two University buildings formerly used as athletic dormitories. These buildings have been reconditioned and extended for Laboratory purposes. Equipment has been supplied by the Bureau of Ordnance largely from available surplus stocks.

Members of the Society for Promotion of Engineering Education, who are staff members of the Defense Research Laboratory, include: M. J. Thompson, M. V. Barton, Dana Young, B. E. Short, H. E. Brown and M. L. Begeman.

Virginia Polytechnic Institute. A committee of the engineering faculty has prepared an illustrated manual for engineering instructors entitled "Effective Teaching," *Engineering Extension Bulletin* No. 42. Written with an economy of words and in the language of the engineer, it presents in a clear and forceful manner the essentials of good instruction, as well as some thought-provoking ideas on education in general.

The introduction is given to the consideration of the objectives of engineering education, and to just what type of training a student should have in order to perform properly his duties as a professional man, and to take his rightful place in a very complex social and economic order. The body is divided into five parts as follows: Designing the Course; Planing the Individual Lesson; Teaching Aids and How to Use Them; Teaching the Class; and Critique of Your Work and Methods. At the end is a Course and Instruction Rating Sheet to be used in having the students rate the instructor on the effectiveness of his teaching.

This manual was prepared primarily for the benefit of the V.P.I. staff but, in the interest of engineering education, it is being made available to other colleges interested in raising their standards of instruction. The first copy is sent free but a charge of ten cents each is made for additional copies to cover the cost of printing. Requests for copies should be sent to Earle B. Norris, Dean of Engineering, V.P.I., Blacksburg, Virginia.

The Summit Corporation, Scranton, Penna., was recently organized to carry on fundamental research in the fields of electrical, mechanical, and chemical engineering, and electronic physics. Otto J. M. Smith is the chief electrical engineer of the new corporation.

Dean Frederick M. Feiker, Chairman, Division of Engineering and Industrial Research of the **National Research Council** announces the appointment of Louis Jordan as Executive Secretary of the Division. Mr. Jordan has recently been Executive Secretary of the War Metallurgy Committee and Head Technical Aide, War Metallurgy Division of NDRC.

This appointment of an experienced research administrator as Executive Secretary of the Division of Engineering and Industrial Research is in line with the plans of the National Research Council to augment the permanent staff of its technical divisions so as to be better able to continue, in the post war era, the leading part the Council has played during World War II in organizing and coordinating research activities of interest to governmental, industrial and educational institutions.

ERRATA

In the February 1946 year book, R. R. Seeber was listed as Professor and Head of the Department of Mathematics and Mechanics at the University of Minnesota. Professor Seeber holds this position at the Michigan College of Mining and Technology.

The Measurement and Guidance Project in Engineering Education—A Report of Progress and Plans

By K. W. VAUGHN, *Director*

Introduction

The Measurement and Guidance Project in Engineering Education has been conducted during a period when higher education has undergone many changes. In July, 1943, when the Project began operation, colleges of engineering were enrolling classes fairly typical of previous years. Selective Service and war industry had made certain inroads on the student population but, in the main, classes were generally representative of previous years. Shortly, however, civilian engineering students were replaced largely by Army and Navy trainees who were accompanied by curricula superimposed by the Armed Forces. These programs too gave way with the cessation of hostilities. The current class of high school graduates, veterans, and the backlog of those whose educational programs were interrupted by the war are now filling college classrooms with unprecedented numbers. Colleges which only yesterday mourned the loss of students are now faced with the difficult problems of housing and teaching the large number of students who apply for admission. What has the Measurement and Guidance Project accomplished during this period of rapid change? How can the Project assist in the solution of the difficult problems in the postwar period?

This report summarizes the accomplishments of the Project and presents plans for its continuance and extension. The review of the work of the Project includes a discussion of the examinations constructed and a summary of the number of students tested in cooperating institutions. The plans for the future conduct of the Project provide for the extension of the system of guidance and achievement examinations, continuance of the program of research into the effectiveness of the various examinations constructed, and a series of reports which will bring the accomplishments of the Project to the attention of engineering educators.

A Review of the Work of the Project

The statement of purpose of the Project approved by the Engineers' Council for Professional Development, the Society for the Promotion of Engineering Education, and the Carnegie Foundation for the Advancement of Teaching defined the work of the Project as primarily concerned with the development and refinement of guidance examinations for engineering students. Guidance tests were proposed for freshman students and for end-of-year sophomore engineering students. This first phase of the work is nearing completion.

The series of freshman entrance examinations were first constructed and studied. This series of tests, the *Pre-Engineering Inventory,* was first used in the fall of 1943. Revised for the third time late in the summer of 1944, the Inventory has been administered to more than 35,000 individuals. Table 1 lists the names of all institutions which have cooperated formally in the Project during the period July 1, 1943 to June 1, 1946. More than 15,000 students and others not enumerated in Table 1 have taken all or part of the

TABLE 1

NUMBER OF STUDENTS TESTED IN COOPERATING COLLEGES OF ENGINEERING*
July 1, 1943 to June 1, 1946

Institution	1943–44	1944–45	1945–46	Total
Alabama, University of		133	392	525
Brooklyn College		121	91	212
Brooklyn, Polytechnic Institute of		100	322	422
California Institute of Technology	119	100	135	354
California, University of (Berkeley)		409	442	851
California, University of (Los Angeles)		54	457	511
Carnegie Institute of Technology	105	348	1,531	1,984
Case School of Applied Science		298	617	915
Detroit, University of		140	328	468
General Electric Company		141	55	196
Georgia School of Technology		284	1,014	1,298
Illinois Institute of Technology			197	197
Illinois, University of			388	388
Iowa, State University of	119	47		166
Louisville, University of			47	47
Maine, University of		51	273	324
Massachusetts Institute of Technology		457		457
Michigan College of Mining and Technology		58	326	384
Michigan, University of	213	395	559	1,167
Newark College of Engineering	336	280	633	1249
New Mexico College of A. & M.		30	19	49
North Carolina State College	325	689	850	1,864
Northwestern University	87	126	136	349
Oklahoma A. & M. College		175	46	221
Oregon State College		115		115
Purdue University			733	733
Renssalaer Polytechnic Institute			452	452
Rose Polytechnic Institute		33	24	57
Stanford University		322	103	425
Tennessee, University of	49	109	135	293
Texas, University of	350	521	1,115	1,986
Toronto, University of		558		558
Tufts College			321	321
Tulane University of Louisiana		63	345	408
Wayne University			153	153
Wyoming, University of		51	68	119
Total	1,703	6,208	12,307	20,218

* Does not include approximately 15,000 others not classified as students in cooperating institutions.

Pre-Engineering Inventory. These students were tested under varying circumstances, primarily in connection with the training programs of various branches of the Armed Services, and are not classified as regular freshman engineering students.

The records for all of these individuals are carefully preserved in the Project files and serve as a reservoir of data for research purposes. As rapidly as time and funds permit, the Project Staff is completing analyses of these data. The preliminary researches into the effectiveness of the Inventory for purposes of predicting success in the first year of engineering study provided the basis for two revisions of these tests; future forms of this series of tests will be based on the outcomes of research now in progress.

The second series of tests, the *Sophomore Achievement Tests for Engineering Students,* are now in experimental form. These tests were developed by the Measurement Committee representing the cooperating colleges. Tests in engineering drawing, mathematics, physics, inorganic chemistry, and English have been prepared for experimental trial and will be administered in representative colleges during the present academic year. It is expected that the final forms of these tests, complete with tentative norms, will be available for the use of cooperating institutions by September 1, 1946. The first nationwide administration of these tests will be conducted in February or March, 1947.

In summary, the work of the Project has been concerned primarily with the development and construction of the tests in the two series described above, the reporting of test results to the cooperating colleges, and the conduct of researches into the effectiveness of the Pre-Engineering Inventory. The refinement of the Inventory, the reporting of test results, and a large part of the research work have been completed on schedule. The achievement tests were postponed one year in view of the uncertain conditions prevailing in 1945.

Plans

Since its beginning, the Measurement and Guidance Project has been handicapped by the irregular conditions in engineering education. Atypical classes, heavy losses of students to the Armed Services, and many other abnormal conditions have contributed to the difficulties of studying the educational progress of engineering students. Few freshmen were permitted to complete the third or fourth semesters of study, and colleges frequently protest that the curricula offered during the war years were not typical of that which had been offered before the war; hence the studies of prediction conducted during the wartime period may have decided limitations for peacetime purposes. While these studies have thrown important light on the problems of measurement for prediction of success in the college of engineering, considerable work must be done to determine the extent to which these preliminary findings pertain to engineering education under normal conditions.

With these facts in mind, the Project Staff has outlined plans whereby the Project may be conducted on a continuing basis. These plans are presented under appropriate headings in the following paragraphs.

The Pre-Engineering Inventory

Among the cooperating colleges of engineering, opinion concerning the

value of the Pre-Engineering Inventory appears to be quite uniform. Most colleges have discovered that this series of tests have been more valuable for predicting success of freshman students than tests used previously. The confidence in the Inventory is most gratifying. It is certain, however, that the present form of the Pre-Engineering Inventory must be supplemented by other forms constructed in the same manner and perhaps improved still further.

Plans concerning the development of the Inventory are summarized as follows:

1. During 1946–47, two new forms of the Inventory will be constructed and administered experimentally in a number of representative colleges of engineering.
2. Research pertaining to this series of tests will be collated and used in the refinement of the new series of Inventories.
3. Forms B and C will be equated to Form A and adjusted to the same difficulty so that comparable scores over a period of years can be obtained for research and institutional purposes.
4. The raw scores of these tests will be scaled and reported in terms of scaled scores. These scaled scores will be based on the performance of engineering freshmen in general, thus providing scores which are immediately comparable to the performance of freshman engineering students without translation into percentile ranks.
5. It is probable that the Inventory will be shortened in point of administration time. The further refinement of the measurement employed may result in shorter tests which have the same, or perhaps even greater, effectiveness.
6. It is hoped that interest in a nation-wide program and funds will permit the establishment of a number of Examination Centers throughout the United States which will administer the Inventory to high school graduates immediately previous to their graduation from high school. The results of these examinations may then be forwarded to colleges of engineering for purposes of evaluation and admission.
7. After July 1, 1946, all test materials sent from the Project Office will be forwarded in sealed packages. These packages will contain all of the materials needed by the student. These procedures will greatly simplify the work of the examiners in cooperating colleges.
8. Improved methods of reporting results of the Inventory will be placed in operation on July 1, 1946. These methods provide for the preparation of five individual profiles: one for the student, where this is desired; two for the office of the Dean or the Student Counselor in the cooperating colleges; and two for the files of the Project Office.
9. The Project Office will render institutional reports in the future which are much more comprehensive than those presented during the past year. During the first year of the Project, it was possible for the Director to write a personal report to each cooperating college of engineering. This practice will be resumed after July 1, 1946.

It is the intent of the Project to perfect its entrance examinations so that they will become as effective for this purpose as it is possible to construct objective tests. The large-scale activities of the Project preclude the use of other than objective tests, but it is certain that the possibilities of this method of examination have not been fully realized.

The Sophomore Achievement Tests

A system of guidance tests for college students must provide for a series of tests appropriate for measuring the

achievement of students who have completed or will soon complete the sophomore year. The purpose of tests at this level is to provide a general measure of the potentiality of the individual for further study in engineering. Such tests should be administered early in the fourth semester or late in the fifth quarter of the usual academic year. The results of these tests must be immediately available to deans and guidance officers. During the period remaining in the school year, the students may be informed of their performance on the tests and advised concerning their potentialities for further study in engineering.

Plans concerning the sophomore achievement tests are summarized as follows:

1. Experimental forms of the following tests will be administered during the current academic year: engineering drawing, physics, inorganic chemistry, mathematics, and English. These tests will then be revised and assembled in final form.
2. The completed tests will be placed at the disposal of all cooperating colleges of engineering for the purpose of preparing tentative norms. These norms will be published and distributed as soon as they have been obtained. It is expected that the first tentative forms of the new norms will be available during the early fall of 1946.
3. The Sophomore Achievement tests will be confidential in character. Colleges of engineering participating in the Project, however, will be able to administer them in whole or in part during any part of the year for purposes of obtaining information concerning students who are regularly enrolled or who apply for advanced standing in the college of engineering.
4. Colleges will be provided with a supply of these tests which may be retained over a period of time. Scoring keys will also be provided so that results for individual students can be obtained immediately after completion of the tests. The Project Office will recall all test booklets from time to time and will receive all answer sheets for record. When answer sheets are returned to the Project Office, they will be rescored and a complete institutional report made in the same manner as that employed with the Pre-Engineering Inventory.
5. The tests represented in the first series of achievement tests will be supplemented with tests in other subjects as rapidly as it is possible to develop and construct them.
6. After the first year of use of these examinations, new forms of the Sophomore Achievement tests will be developed. This second series of tests will be based on the experience of the Project Office and the cooperating colleges with the first series. It is probable also that it will be necessary to print several different editions of these tests in order to meet the needs of different types of undergraduate programs.
7. In accordance with the original plans, the Project will conduct a nationwide testing program in all cooperating colleges each spring. The purpose of this program will be to provide the Sophomore Achievement tests to cooperating institutions and to obtain norms for students who are soon to complete their sophomore year of engineering study. With this basic reference point as a measure, the guidance of individuals and groups of students will be greatly facilitated.

The Sophomore Achievement tests will meet a very great need in engineering education. Their construction has involved compromises with existing curricula, but these compromises can be removed very largely when a greater number of institutions make use of the tests. It will be possible, for example,

to prepare mathematics examinations which cover two or three patterns of instruction during the first two years of engineering study. In the preparation of the achievement examinations, the Measurement Committee will remain sensitive to the need of different types of institutions and will attempt to meet these needs in the examinations developed. It is recognized that the uniformity possible with the Pre-Engineering Inventory will not be possible or desirable in certain subjects represented in the achievement examinations. As a point of departure, however, the tests in the first series will be uniform in character with the exception of the mathematics examinations which are printed in units so that colleges may select the combination of tests which best represents their mathematics curriculum for freshman and sophomore engineering students.

A Proposed Series of Tests for Senior Engineers

As orignally conceived, the Project was concerned with only the prediction of success during the first years of engineering education. As this work progressed, it became increasingly apparent that student achievement during this phase of engineering education could not be completely understood without projecting the prediction to its logical conclusion—graduation from the engineering college. It has been pointed out by many educational writers that course marks provide a very difficult criterion to evaluate from an objective standpoint. Standards among colleges are known to vary tremendously; standards of marking and grading within the same college show the same remarkable variation. For purposes of research, it is desirable that measures of the success of advanced students be expressed in objective and comparable terms. Examinations provide this basis.

It is proposed, therefore, that the Measurement and Guidance Project undertake the construction of tests specifically designed to measure the outcomes of the several branches of engineering training. This series of tests would be appropriate only for the advanced senior student who has specialized in one of the several branches of engineering or an individual who has completed studies corresponding to this training. It is believed that tests can be constructed which will be suitable for this purpose, tests which will provide a general measure of the extent to which individual students have attained the aims and objectives of professional training in their field.

The problems of constructing a test covering the professional training of engineers are many and varied. It is believed that special examinations will be needed in each major field. It may be possible to combine certain fields, but at present this appears to be unlikely. It is probable, however, that the complete analysis necessary for the basis of examination in each of the professional branches of engineering will reveal a common core, that is, a body of knowledge and experience which student engineers acquire irrespective of the special branch of engineering studied. The exact nature of the specialized tests and the general examination, if this proves desirable, will be determined by committees of engineering educators, advisors from industry, and related branches of science.

The development and construction of tests for senior students is an ambitious undertaking. Much effort and considerable funds are necessary. It is

hoped that there will be sufficient interest in this problem to insure the support and cooperation of the best educational viewpoints in engineering education. Funds necessary for the expenses of this Project are available from appropriations to the Graduate Record Office by the Carnegie Foundation for the Advancement of Teaching and Carnegie Corporation of New York. The Measurement and Guidance Project Office is an integral part of the Graduate Record Office and consequently shares in appropriations to this branch of the Carnegie Foundation. It is believed that the funds now available will permit the construction of senior examinations in the most popular branches of engineering. Other examinations can be constructed as the need arises and the funds become available.

The values of senior examinations to engineering education are too numerous to consider in this report. It is certain that the study and evaluation of aims, objectives, curricula practises, and other aspects of the educational program which must be taken into account in the development of such examinations would prove most stimulating and valuable to educators generally. If examinations for senior engineers are developed and are successful in their purpose, wide application to a number of educational problems is assured.

A High School Series of Guidance Tests

The Project is soon to undertake the development and construction of a series of tests for high school students who are contemplating the study of engineering. These tests will be adjusted to the abilities of high school sophomore students so that curricula suitable for pre-engineering training could be followed during the last years of high school.

This series of tests would provide high school teachers and guidance officers with a measure of the potentiality of high school students for engineering study. It is imperative that students in the secondary schools receive proper guidance if they are to succeed during the first years of engineering study. It is believed that the Project can assist secondary school guidance officers by providing such a series of tests. It is expected also that it will be feasible to prepare a brochure addressed to high school students which will advise them on the basis of the results obtained from this series of guidance tests.

One of the most important uses of this proposed series of tests is to obtain a measure of the abilities of a large number of students while they are still enrolled in high school. By conducting a large testing program in secondary schools, it will be possible to obtain information concerning the relative abilities of those who later choose engineering as a life work, those who elect other college curricula, and what may be of most significance, those who do not go to college.

Reports to be Prepared

The work of the Measurement and Guidance Project will be understood and appreciated only in relation to the extent to which it can prepare intelligible and significant reports. The uncertain conditions of the war period have interfered with the reporting of all of the research that has been completed. The Project Office, however, is preserving all of its work and relating the findings to new data as they are collected.

In general, the pattern of reports is as follows:

1. Institutional reports are made periodically to each cooperating institution. These reports provide much of the data for the comprehensive reports which appear periodically.
2. A report of Summer and Fall Testings —Norms for public, private, and all cooperating colleges. This report will ordinarily appear in February, although tentative norms will be sent to cooperating colleges in October.
3. A Yearly Report of All Testings—Norms for public, private, and all cooperating colleges as well as a report of the personal characteristics of all students tested.
4. Research Reports—Institutional reports and general reports. Each institutional report is confidential in character; the general reports are published in the Journal of Engineering Education and in the Annual Report of the Engineers' Council for Professional Development.
5. General Report—It is expected that a general report will be prepared when the Project has reached a mature stage. This report will be book-length and will summarize all of the findings of the Project since its beginning.

Evaluation

In constructing and perfecting guidance and achievement examinations, the Measurement and Guidance Project is concerned with one of the most important tools of the educator. Examinations can provide a dependable basis for the guidance of individual students, the evaluation of the results of learning during an interval of time, and perhaps which is of most importance, serve as a focus in the study of curricula and educational programs. The principal purpose of all examinations is to provide a measure of some aspect of educational development. In this sense, examinations serve to "test" students in much the same way in which engineers test raw materials, various stages of manufacture or processing, and the quality of the final product. However good the raw materials and the manufacturing processes, some elimination is necessary all along the line from the first stage to the final product. The more precise the "test" the better the product when it meets the standards established.

No professional curriculum has as yet erected a system of examinations or "tests" designed to measure the quality of its raw materials and the several stages involved in producing its final products—graduates. Consequently, no professional curriculum has been studied systematically from the point of view of student selection, elimination, and achievement in relation to objectives of the curriculum. Indeed, only a few college curricula have attempted to develop tests which are specifically designed to measure the type of raw material that is best suited to their particular manufacturing processes. Until uniform and comparable measures are available, much of the educational program in colleges must be taken for granted, or assumed on the basis of the preparation of teachers, the success of their students, and similar subjective bases for evaluating the educational process.

The Measurement and Guidance Project has already made significant strides in the development of a series of freshman entrance examinations. The Pre-Engineering Inventory is essentially a test of the quality of the raw materials of the engineering profession. Results for wartime classes revealed such wide variation in quality that systematic inquiry is suggested. The Project plans to undertake this

inquiry and to provide engineering colleges with the results. The assay of raw materials does not, of course, determine the final product. With the completion of the achievement examinations for sophomore students, additional data concerning the achievement of various types of students will become available. It will be possible to determine those who were eliminated from college study, those who dropped out of their own accord, and those who remained to graduate. If the proposed tests for senior students are undertaken and completed to the satisfaction of the engineering profession, it is expected that the facts revealed by systematic study of thousands of students in many colleges of engineering will throw added light on the whole character of undergraduate engineering education.

The early and favorable start in the development of systematic series of tests at two levels in engineering education is definitely encouraging. If the opportunities presented in the present Project are fully realized, it may well be that engineering educators will be first to perfect an examination structure which can reveal the extent to which institutions and individuals realize the goals established for engineering curricula. If, through the study of the progress of individuals, we can ascertain the factors which determine success, we will be provided with those facts which are the true basis for student guidance.

Subject Index, 1945-46

ACADEMIC TENURE, PROFESSIONAL SERVICE AND RESPONSIBILITY, REPORT ON. C. J. Freund....10, 601
ACCELERATED PROGRAM, RETURNS FROM A QUESTIONNAIRE ON. J. W. Stewart....3, 188
ADDRESS. H. S. Rogers....1, 10
ADMINISTRATIVE DIVISION. 1, 23; 2, 161; 3, 238; 4, 245
ADMINISTRATION, AN EXPERIMENT IN COURSE. P. H. Black....8, 512
ADVICE TO YOUNG MEN WHO SEEK CAREERS IN CIVIL ENGINEERING. L. O. Stewart....1,36
AIRPLANE STRUCTURES, OBJECTIVE OF A LABORATORY COURSE IN. N. J. Hoff....4, 262
AMBASSADOR OF GOOD WILL. S. S. Steinberg....2, 160
ANALYTIC GEOMETRY, FURTHER NOTES ON. S. B. Folk....5, 376
ANALYTICAL STATISTICS IN INDUSTRY. Holbrook Working....7, 407
ARE WE OVEREMPHASIZING SCIENCE AND TECHNOLOGY? D. L. Arm...2, 139
ARMY TRAINING METHODS ENTER THE ENGINEERING COLLEGE. K. A. Kobe....1, 66
ATOMIC BOMB, SMYTH REPORT ON DEVELOPMENT OF THE....2, 145
ATOMIC ENGINEERING. Theodore von Karman....4, 247
AUDIO-VISUAL AIDS IN ENGINEERING INSTRUCTION, USE OF. C. L. Baker and W. G. Gnaedinger....3, 175

BEST AND WORST TEACHERS OF ENGINEERING, THE. K. S. Davenport, H. H. Remmers, A. A. Potter....4, 296
BINOMIAL COEFFICIENTS. Harry Sohon....7, 414
BUILDERS OF THE BRIDGE. John C. Riedel....10, 657

CAN HUMANISTIC-SOCIAL STUDY BE MADE ENGINEERING EDUCATION? Elliot D. Smith....2, 134
CENTURY OF AMERICAN TEXTBOOKS IN MECHANICS AND RESISTANCE OF MATERIALS. J. O. Draffin....3, 221
CIVIL ENGINEERING CURRICULUM, HYDROLOGY IN THE. H. W. Wood...8, 519
SUGGESTED IMPROVEMENT OF THE POST-WAR UNDERGRADUATE. J. B. Wilbur....2, 141
ADVICE TO YOUNG MEN WHO SEEK A CAREER IN. L. O. Stewart....1, 36
CONDENSATION OF A REPORT ON COURSE XV, M.I.T. R. W. King....10, 634
CONSTITUTION AND BY-LAWS:
A REPORT OF ACTIVITIES OF COMMITTEE ON REVISION OF. H. S. Rogers..1, 4
BACKGROUND OF PROPOSAL FOR REVISION OF. H. S. Rogers....2, 89
OUTLINE OF PROPOSED CONSTITUTION STRUCTURE OF THE SOCIETY. Robert E. Doherty....7, 401
A PROPOSED REVISION OF. H. O. Croft....8, 469
CONSTITUTION AND BY-LAWS. H. S. Rogers....10, 599
COOPERATIVE ENGINEERING EDUCATION FOR THE TEACHER INDUSTRY'S OPPORTUNITY. W. J. Seeley....3, 207
DISCUSSION: M. L. Manning....7, 451
COOPERATIVE COURSES AT THE UNIVERSITY OF CINCINNATI, ORIGIN AND DEVELOPMENT OF. C. W. Park...7, 420
COUNCIL, MEETING OF....1, 6
CREATIVE ENGINEERING RESEARCH: ITS STIMULATION AND DEVELOPMENT. W. R. Woolrich....9, 565
CREDITS FOR IN-SERVICE COURSES, REPORT ON COLLEGE. O. J. Ferguson.1, 73
CURRICULUM MAKING, SOME PRINCIPLES OF. L. O. Stewart....5, 354

DEVELOPING CREATIVE ENGINEERS. J. F. White....4, 305
DO WE REALLY NEED ENGINEERS AND SCIENTISTS? Allan R. Cullimore..5, 320

EDUCATION FOR A CHANGING WORLD. B. R. Van Leer....7, 434
EDUCATION FOR THE ENGINEERING PROFESSION. Alan Hazeltine....2, 120
EDUCATIONAL RESEARCH, RECONVERSION OF. L. E. Beck....3, 215
ENDLESS HORIZONS, THE QUALITIES OF A PROFESSION—. Vannevar Bush..7, 463

ENGINEERING EDUCATION? SHOULD HUMANISTIC-SOCIAL STUDY BE MADE. A. C. Ames....9, 543
ENGINEERING IN THE MIDDLE AGES, FURTHER NOTES ON. J. K. Finch.5, 378
ENGINEERING DURING MIDDLE AGES AND THE RENAISSANCE, THE STATUS OF. J. O. Draffin....2, 91
ENGINEERING DEVELOPMENT DURING WORLD WAR II. L. K. Sillcox Year Book
ENGINEERING STUDENT ENROLLMENT GROWING, BUT FAR FROM NORMAL W. B. Plank....9, 572
ENGINEERING ECONOMY IN RETROSPECT, S.P.E.E. COMMITTEE ON. P. T. Norton....1, 79
ENGINEERING ENROLLMENT FOR 1945–46. 5, 388
ENGINEERS, DEVELOPING CREATIVE. J. F. Young....4, 305
ENGINEERING COLLEGE RESEARCH ASSOCIATION:
PROBLEMS AND ORGANIZATION NEEDS OF. W. R. Woolrich....5, 315
REPORT OF COMMITTEE ON LEGISLATION. C. E. MacQuigg....9, 579
REPORT ON COMMITTEE ON ACADEMIC TENURE, PROFESSIONAL SERVICE AND RESPONSIBILITY. C. J. Freund..10, 601
ENGLAND, TECHNICAL EDUCATION FOR ENGINEERS IN. W. Abbott....10, 653
E.S.M.W.T. AND ITS PERMANENT LESSONS FOR AMERICAN ENGINEERING SCHOOLS, THE WAR PROJECT CALLED. F. D. Carvin and D. C. Jackson....5, 327
ENGLISH AND THE HUMANISTIC-SOCIAL DIVISION. K. O. Thompson....3, 136
EVOLUTION OF A POLICY. A. W. Buchan 4, 250
EXPERIMENT IN COURSE ADMINISTRATION, AN. P. H. Black....8, 512
EXPLORATIONS IN ENGINEERING EDUCATION. A. B. Bronwell....2, 124

FACULTIES, WHAT ABOUT OUR? H. P. Hammond and E. A. Walker....7, 447
FOREGIN SERVICE AND THE FOREIGN STUDENT, A NOTE ON. J. K. Finch....5, 378
FUNCTIONS OF HISTORY IN THE ENGINEERING CURRICULUM, THE. S. W. Chapman....4, 272
FURTHER NOTES ON ANALYTIC GEOMETRY. S. B. Folk....5, 376
FURTHER NOTES ON ENGINEERING IN THE MIDDLE AGES. J. K. Finch..5, 378
FUTURE OF MECHANICAL ENGINEERING EDUCATION, A REPORT ON. Colin Carmichael....1, 55

GEOMETRY, FURTHER NOTES ON ANALYTIC. S. B. Folk....5, 376
GROUND SCHOOL AND ENGINEERING SCHOOL: SOME NOTES ON TRAINING G. D. Stout....10, 612

HISTORY IN THE ENGINEERING CURRICULUM, THE FUNCTIONS OF. S. W. Chapman....4, 272
HORIZONTAL OPTIONS THROUGH MAJOR ENGINEERING CURRICULA—ONE SOLUTION TO THE 4-YEAR QUANDARY L. E. Grinter....8, 542
HOW DO YOU DO? A. M. Hill....3, 209
HOW TO SELECT NEW MEMBERS AND PROMOTE OLD ONES ON OUR ENGINEERING STAFFS. D. T. Canfield..1, 43
HUMANISTIC-SOCIAL STUDIES:
CAN HUMANISTIC-SOCIAL STUDY BE MADE ENGINEERING EDUCATION? Elliott D. Smith....2, 134
CHARACTERISTICS OF THE HUMANISTIC-SOCIAL STUDIES IN ENGINEERING EDUCATION. R. M. Boarts and John Hodges....5, 339
ENGLISH AND THE HUMANISTIC-SOCIAL DIVISION. K. O. Thompson....3, 163
A HUMANISTIC-SOCIAL OVERHAULING. C. J. Freund....4, 284
HUMANISTIC-SOCIAL STUDIES IN ENGINEERING—ANOTHER VIEWPOINT. S. F. Borg....7, 424
HUMANISTIC AND SOCIAL SCIENCE SUBJECTS IN RELATION TO THE ENGINEERING CURRICULUM. F. W. Roys.3, 203
INTRODUCTION TO REPORT ON. H. P. Hammond....5, 338
SHOULD HUMANISTIC-SOCIAL STUDY BE MADE ENGINEERING EDUCATION? A. C. Ames....9, 543
HYDROLOGY IN THE CIVIL ENGINEERING CURRICULUM. H. W. Wood....8, 519

I THINK——. B. F. Bailey....10, 621
IF I WERE AN ENGINEER. R. R. Price.8, 496
ILLINOIS, SENIOR SEMINAR COURSE AT THE UNIVERSTIY OF. E. A. Reid...1, 33
INSPECTION PRACTICE AND PROCEDURES IN THEIR RELATIONS TO MECHANICAL ENGINEERING. Roland Jenkins 1, 26
INTRODUCTORY COURSE IN ADMINISTRATION FOR ENGINEERS. Harry Rubey....3, 185

M.I.T., Condensation of Report on Course XV. R. W. King.....10, 634
Mathematics, U. S. Armed Forces Institute Examinations in Mathematics As a Means of Determining Credit in. J. H. Zant.....3, 170
Recommendations for High School. W. J. Seeley.....1, 48
Measurement and Guidance Project in Engineering Education: A Progress Report. K. W. Vaughn 2, 111; 10, 676
Mechanical Engineering, Inspection Practice and Procedures in their Relation to. (Roland Jenkins.....1, 26
Mechanics Division.....1, 81
Mechanics and Resistance of Materials, A Century of American Textbooks on. J. O. Draffin.....4, 221
Meeting, Council.....1, 6
Methods in Engineering Laboratory Instruction. J. R. White.....1, 50
Middle Ages and the Renaissance, The Status of Engineering During the. J. O. Draffin.....3, 221
Middle Ages, Further Notes on Engineering in the. J. K. Finch 5, 378
National Spokesman for Engineering, A. A. R. Stickney.....8, 515
Necrology:
George Frederick Eckhard.....7, 458
Matthias E. Haas.....1, 88
Adam Hofmann.....1, 88
Homer Heath Nugent.....2, 152
Harry Speer Rush.....4, 283
Need Engineers and Scientists? Do We Really. Allan R. Cullimore 5, 320
Nomographic Representation of Polynomials. W. H. Burrows.....5, 361
Note on Foreign Service and the Foreign Student. J. K. Finch.....5, 378
Objectives of a Laboratory Course in Airplane Structures. N. J. Hoff.....4, 262
Origin and Development of Cooperative Courses at the University of Cincinnati. C. W. Park.....7, 420
Outline of Proposed Constitutional Structure of the Society. Robert E. Doherty.....7, 401

Patent Policies for Sponsored Research. R. A. Morgen.....10, 618
Physics Column:.....1, 82; 2, 153; 3, 240; 4, 302; 5, 387; 7, 462; 8, 542
Physics Curriculum, Some Comments on the Engineering. A. O. Williams.....2, 146
Policy, Evolution of A. A. W. Buchan.....4, 250
Polynomials, The Nomographic Representation of. W. H. Burrows 5, 361
Post-War Undergraduate Training for Engineers. O. S. Bray.....3, 211
Post-War Training for Signal Corps Reserve Officers. C. W. Janes and J. O. Sweeney.....4, 299
Professional Engineering Life, Teaching the Facts of. E. A. Holbrook.....2, 155
Prony Brake, The. P. M. Honnel.....3, 193
Quest of Knowledge, The. B. Howland.....4, 302
Recommendations for High School Mathematics. W. J. Seeley.....1, 48
Reconversion of Educational Research. L. E. Beck.....3, 215
Refresher Courses, A Phase of Continuation Education. L. O. Stewart.....3, 180
Renaissance, The Status of Engineering During the Middle Ages and the. J. O. Draffin.....2, 91
Reports:
Academic Tenure, Professional Service and Responsibility. C. J. Freund.....10, 601
Activities of Committee on Revision of Constitution and By-Laws. H. S. Rogers.....1, 2
College Credits for In-Service Courses. O. J. Ferguson.....1, 73
E.C.R.A. Committee on Legislation. C. E. MacQuigg.....9, 579
Future of Mechanical Engineering Education. Colin Carmichael 1, 55
1st Annual Industry-Agricultural Week at Kansas State College. A. L. Pugsley.....8, 502
Humanistic-Social Studies in Engineering Education.....5, 338
Secretary, F. L. Bishop.....1, 18
Treasurer, J. S. Thompson.....1, 20
Research: Its Stimulation and Development, Creative Engineering. W. R. Woolrich.....9, 565
Research Corporation and Its Service to Engineering and Scientific Research. W. R. Woolrich..7, 404

RESPONSIBILITY, A GREAT. L. K. Sillcox....9, 547
RETURNS FROM THE QUESTIONNAIRE ON ACCELERATED PROGRAMS. J. W. Stewart....3, 188
REVISION OF CONSTITUTION AND BY-LAWS:
CROFT, H. O....8, 469
DOHERTY, ROBERT E....7, 401
ROGERS, H. S....1, 4; 2, 89; 10, 599
WOOLRICH, W. S....5, 315

SELECTIVE SERVICE. M. H. Trytten 10, 626
SCIENCE AND TECHNOLOGY? ARE WE OVEREMPHASIZING. D. L. Arm...2, 139
SENATE, THE UNIVERSITY OF PITTSBURGH. Rufus H. Fitzgerald.... 1, 14
SENIOR SEMINAR COURSE AT THE UNIVERSITY OF ILLINOIS. E. A. Reid..1, 32
SERVOMECHANISMS COURSES—THEIR PEDAGOGIC VALUE. D. P. Campbell....7, 426
SHOULD ENGINEERS STUDY STATISTICS? Holbrook Working....9, 557
SIGNAL CORPS RESERVE OFFICERS, POST-WAR TRAINING FOR. C. W. James and J. O. Sweeney....4, 299
S.P.E.E. COMMITTEE ON ENGINEERING ECONOMY IN RETROSPECT. P. T. Norton....1, 79
S.P.E.E. AMBASSADOR OF GOOD WILL. S. S. Steinberg....2, 160
SOME COMMENTS ON ENGINEERING PHYSICS CURRICULUM. A. O. Williams....2, 146
SOME PRINCIPLES OF CURRICULUM MAKING. L. O. Stewart....4, 354
STATISTICS, SHOULD ENGINEERS STUDY? Holbrook Working....9, 557
STATISTICS IN INDUSTRY, ANALYTICAL. Holbrook Working....7, 407
STATUS OF ENGINEERING DURING THE MIDDLE AGES AND THE RENAISSANCE. J. O. Draffin....2, 91
STREAMLINE GRAPHICS. J. P. Vidosic 4, 282
SUGGESTION FOR ENGINEERING EDUCATION. A. L. E. Moore....3, 198
SUGGESTED IMPROVEMENT OF THE POST-WAR UNDERGRADUATE CIVIL ENGINEERING CURRICULUM. J. B. Wilbur....2, 141

TEACHING THE FACTS OF PROFESSIONAL ENGINEERING LIFE. E. A. Holbrook....2, 155
TEACHING AND PRACTICING ELECTRICAL DESIGN. N. M. Oboukhoff....8, 522
TEACHERS OF ENGINEERING, THE BEST AND WORST. K. S. Davenport, H. H. Remmers, A. A. Potter....4, 296
TECHNICAL EDUCATION FOR ENGINEERS IN ENGLAND. W. Abbott....10, 653
TECHNOLOGY? ARE WE OVEREMPHASIZING SCIENCE AND. D. L. Arm....2, 139
TEXTBOOKS IN MECHANICS AND RESISTANCE OF MATERIALS, A CENTURY OF AMERICAN. J. O. Draffin....3, 221
TRAINING FOR THINKING—OR MASS PRODUCTION OF ROBOTS? L. M. Duryee....4, 292
TRANSCRIPT—DOCUMENT OR! J. P. Vidosic....5, 352
TREASURER, REPORT OF. J. S. Thompson. 1, 20
T-SQUARE PAGE....1, 84; 7, 455

U.S.A.F.I. EXAMINATIONS IN MATHEMATICS AS A MEANS OF DETERMINING CREDIT IN ENGINEERING MATHEMATICS. J. H. Zant....3, 170
U. S. NAVAL POSTGRADUATE SCHOOL. H. A. Spanagel....4, 280
UNIVERSITY OF PITTSBURGH SENATE, THE. Rufus G. Fitzgerald....1, 14
USE OF AUDIO-VISUAL AIDS IN ENGINEERING INSTRUCTION. C. L. Barker and W. G. Gnaedinger....3, 175

WAR PROJECT CALLED E.S.M.W.T. AND ITS PERMANENT LESSONS FOR AMERICAN ENGINEERING SCHOOLS. F. D. Carvin and D. C. Jackson....5, 327
WHAT ABOUT OUR FACULTIES? H. P. Hammond and E. A. Walker....7, 447
WORLD WAR II, ENGINEERING DEVELOPMENT DURING. L. K. Sillcox. Year Book
WRITING LABORATORY COURSE, A. Frederick Abbuhl....4, 269

YOU'RE NEVER TOO OLD TO LEARN. A. R. Stevenson....4, 256

Authors' Index, 1945-46

ABBOTT, W., Technical Education for Engineers in England....10, 653
ABBUHL, FREDERICK, A Writing Laboratory Course....4, 269
AMES, A. C., Should Humanistic-Social Study Be Made Engineering Education?....9, 543
ARM, D. L., Are We Overemphasizing Science and Technology?....2, 139

BAILEY, B. F., I Think----....10, 621
BARKER, C. L., AND W. G. GNAEDINGER, Use of Audio-Visual Aids in Engineering Instruction....3, 175
BECK, L. E., Reconversion of Educational Research....3, 215
BISHOP, F. L., Report of Secretary....1, 18
BLACK, P. H., An Experiment in Course Administration....8, 512
BOARTS, R. M., AND JOHN HODGES, Characteristics of the Humanistic-Social Studies in Engineering Education....5, 339
BORG, S. F., Humanistic-Social Studies in Engineering—Another Viewpoint .7, 424
BRAY, O. S., Post-War Undergraduate Training of Engineers....3, 211
BRONWELL, A. B., Explorations in Engineering Education....2, 124
BUCHAN, A. W., Evolution of a Policy..4, 250
BURROWS, W. H., The Nomographic Representation of Polynomials....5, 361
BUSH, VANNEVAR, The Qualities of a Profession—Endless Horizons....7, 463

CAMPBELL, D. P., Servomechanisms Courses—Their Pedagogic Value..7, 426
CANFIELD, D. T., How to Select New Members and Promote Old Ones on Our Engineering Staffs....1, 43
CARMICHAEL, COLIN, Future of Mechanical Engineering Education, A Report on....1, 55
CARVIN, F. D., AND D. C. JACKSON, The War Project Called E.S.M.W.T. and Its Permanent Lessons for American Engineering Schools....5, 327
CHAPMAN, S. W., The Functions of History in the Engineering Curriculum...4, 272
CROFT, H. O., A Proposed Revision of the Constitution of the S.P.E.E....8, 469
CULLIMORE, ALLAN R., Do We Really Need Engineers and Scientists?...5, 320

DAVENPORT, K. S., AND H. H. REMMERS, A. A. POTTER, The Best and Worst Teachers of Engineering....4, 296
DOHERTY, ROBERT E., Outline of Proposed Constitutional Structure of the Society....7, 401
DRAFFIN, J. O., The Status of Engineering During the Middle Ages and the Renaissance....2, 91
A Century of American Textbooks in Mechanics and Resistance of Materials....3, 221
DURYEE, L. M., Training for Thinking—Or Mass Production of Robots?...4, 292

FERGUSON, O. J., Report on College Credits for In-Service Courses....1, 73
FINCH, J. K., Further Notes on Engineering in the Middle Ages....5, 378
A Note on Foreign Service and the Foreign Student....9, 576
FITZGERALD, RUFUS H., The University of Pittsburgh Senate....1, 14
FOLK, S. B., Further Notes on Analytic Geometry....5, 376
FREUND, C. J., A Humanistic-Social Overhauling....4, 284
Report of Committee on Academic Tenure, Professional Service and Responsibility....10, 601

GNAEDINGER, W. G., AND C. L. BARKER, Use of Audio-Visual Aids in Engineering Instruction....3, 175
GRINTER, L. E., Horizontal Options Through Major Engineering Curricula—One Solution to the 4-Year Quandary....8, 542

HAMMOND, H. P., Recipient of the Lamme Award....1, 1
Introduction to Report on Humanistic-Social Studies in Engineering Education....5, 338

HAMMOND, H. P., AND E. A. WALKER, What About Our Faculties? 7, 447
HAZELTINE, ALAN, Education for the Engineering Profession 2, 120
HILL, A. M., How DO YOU DO? . . . 3, 209
HODGES, JOHN, AND R. M. BOARTS, Characteristics of the Humanistic-Social Studies in Engineering Education . . 5, 339
HOFF, N. J., Objectives of a Laboratory Course in Airplane Structures . . . 4, 262
HOLBROOK, E. A., Teaching the Facts of Professional Engineering Life 2, 155
HOLLISTER, S. C., Problems and Organization Needs of the Division of Administrative Officers 3, 161
HONNEL, P. M., The Prony Brake 3, 193
HOWLAND, B., The Quest of Knowledge 4, 302

JACKSON, D. C., AND F. D. CARVIN, The War Project Called E.S.M.W.T. and Its Permanent Lessons for American Engineering Schools 5, 327
JANES, C. W., AND J. O. SWEENEY, Post-War Training for Signal Corps Reserve Officers 4, 299
JENKINS, ROLAND, Inspection Practices and Procedures in Their Relation to Mechanical Engineering 1, 26

KING, R. W., Condensation of a Report on Course XV, M.I.T. 10, 634
KOBE, K. A., Army Training Methods Enter the Engineering College . . . 1, 66

MACQUIGG, C. E., Report of the Engineering College Research Association Committee on Legislation 9, 579
MANNING, M. L., Discussion: Cooperative Engineering Education for the Teacher Industry's Opportunity . . 7, 451
MOORE, L. E., A Suggestion for Engineering Education 3, 198
MORGEN, R. A., Patent Policies for Sponsored Research 10, 618

NORTON, P. T., S.P.E.E. Committee on Engineering Economy in Retrospect 1, 79

OBOUKHOFF, N. M., Teaching and Practicing Electrical Design 8, 522

PARK, C. W., Origin and Development of Cooperative Courses at the University of Cincinnati 7, 420
PLANK, W. B., Engineering Student Enrollments Growing, But Far From Normal 9, 572
POTTER, A. A., Functioning of the Division of Administrative Officers 4, 243
POTTER, A. A., H. H. REMMERS AND K. S. DAVENPORT, The Best and Worst Teachers of Engineering 4, 296
PRICE, R. R., If I Were an Engineer 8, 496
PUGSLEY, A. L., Report of the First Annual Industrial-Agricultural Week at Kansas State College 8, 502

REID, E. A., Senior Seminar Course at the University of Illinois 1, 31
RIEDEL, JOHN C., The Builders of the Bridge 10, 657
REMMERS, H. H., K. S. DAVENPORT, AND A. A. POTTER, The Best and Worst Teachers of Engineering 4,
ROGERS, H. S., Report on Activities of the Committee on Revision of the Constitution and By-Laws 1,
Address 1,
Background of the Proposal for Revision of the Constitution 2,
Summary Statement Upon the Proposed Revisions of the Constitution and By-Laws 10,
ROYS, F. W., Humanistic and Social Science Subjects in Relation to the Engineering Curriculum 3,
RUBEY, HARRY, Introductory Course in Administration for Engineers 3,

SEELEY, W. J., Recommendations for High School Mathematics 1,
Cooperative Engineering Education for the Teacher Industry's Opportunity 3,
SILLCOX, L. K., Engineering Developments During World War II, Year Book A Great Responsibility 9,
SMITH, ELLIOT D., Can Humanistic-Social Study Be Made Engineering Education? 2,
SMYTH Report on Developments of Atomic Bomb 2,
SOHON, HARRY, Binomial Coefficients . 7,
SPANAGEL, H. A., The U. S. Naval Postgraduate School 4,
STEINBERG, S. S., S.P.E.E. Ambassador of Good Will 2,
STEVENSON, A. R., You're Never Too Old to Learn 4,
STEWART, J. W., Returns from the Questionnaire on Accelerated Program 3,
STEWART, L. O., Advice to Young Men Who Seek Careers in Civil Engineering 1,

Refresher Courses, A Phase of Continuation-Education....3, 180
Some Principles of Curriculum Making....5, 354
STICKNEY A. R., A National Spokesman for Engineers....8, 515
STOUT, G. D., Ground School and Engineering School: Some Notes on Training....10, 612
SWEENEY, J. O., AND C. W. JANES, Post-War Training for Signal Corps Reserve Officers....4, 299

THOMPSON, K. O., English and the Humanistic-Social Division....3, 163
THOMPSON, J. S., Report of the Treasurer....1, 20
TRYTTEN, M. H., Selective Service...10, 626

VAN LEER, B. R., Education for a Changing World....7, 434
VAUGHN, K. W., The Measurement and Guidance Project in Engineering Education; A Progress Report 2, 111; 10, 676
VIDOSIC, J. P., Streamline Graphics....4, 282
Transcript—Document OR!....5, 352
VON KARMAN, THEODORE, Atomic Engineering....4, 247

WALKER, E. A., AND H. P. HAMMOND, What About Our Faculties?....7, 447
WHITE, J. R., Methods in Engineering Laboratory Instruction....1, 50
WILBUR, J. B., Suggested Improvements of the Post-War Undergraduate Civil Engineering Curriculum....2, 141
WILLIAMS, A. O., Some Comments on the Engineering Physics Curriculum..2, 146
WOOD, H. W., Hydrology in the Civil Engineering Curriculum....8, 519
WOOLRICH, W. R. Problems and Organization Needs of the Engineering College Research Association....5, 315
The Research Corporation and Its Service to Engineering and Scientific Research....7, 404
Creative Engineering Research: Its Stimulation and Development....9, 565
WORKING, HOLBROOK, Analytical Statistics in Industry....7, 407
Should Engineers Study Statistics?..9, 557

YOUNG, J. F., Developing Creative Engineers....4, 305

ZANT, J. H., U. S. Armed Forces Institute Examinations in Mathematics as a Means of Determining Credit in Engineering Mathematics....3, 170